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SAFETY ASPECTS OF CURB PARKING

Final Technical Report
September 1978
Final Report

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Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Traffic Systems Division
Washington, D.C. 20590

FOREWORD

This report contains detailed documentation of accident and field studies on the effects of on-street parking on safety and traffic operations. The report will be of primary interest to researchers. The research was conducted as part of FCP Project 1A, Traffic Engineering Improvements for Safety, as a result of problem statements from the Federal Highway Administration (FHWA) Office of Traffic Operations, the Texas Highway Department, and the Central Midlands Regional Planning Council of Columbia, South Carolina.

The results indicate that parking related accidents on urban streets are numerous but not very severe. In terms of parking type, angle parking was found to be no more hazardous than parallel parking when land use, parking use, and street type are taken into account. This finding challenges the conclusion of some previous studies of angle parking and the intuition of many traffic engineers. It suggests the need for re-evaluation of on-street parking provisions to include angle parking.

Two copies of the report are being sent to each regional office and three copies to each division office. Two of the division office copies should be sent to each State highway agency.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

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16. Abstract

Parking and accident data were collected on over 170 miles of streets in 10 cities in the U.S.. Over 4,800 accidents were tabulated and analyzed. Intersection and midblock accident comparisons were made for selected cities, and midblock accident rates were computed for various stratifications including street functional classification, land use, parking utilization and parking type.

No relationship was found between accident rate and street width or parking angle. Accident rate was found to vary however with land use (a surrogate variable for parking turnover) and parking utilization. Installation of parking prohibitions was estimated to reduce midblock accident rates from 19% to 75%, which is equivalent to total on-street accident rate reductions (including intersections) of 8% to 30%.

Field operational studies were made relative to the effects of different types of parking on speeds, vehicle placement, delays and conflicts.

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INTRODUCTION AND BACKGROUND

In the early days of urban development, when densities were relatively low, it was frequently possible for motorists to park their automobile on the street near their destination. As densities have increased, curb spaces have become inadequate and parking itself has become a major urban land use. Extensive off-street parking facilities are required on college and university campuses, at airports, stadiums, industrial and office parks, civic centers, shopping centers, and at change of mode points within urban transportation systems.

The responsibility for providing off-street storage space has been said to rest with the automobile owner at the place of residence, the businessman at the place of trade (including parking for both employees and customers or clients), and with the industrial manager in providing parking for employees and visitors.(1) Unfortunately, many citizens and businessmen have failed in the past to accept this responsibility.

This indifference has resulted in many public streets being used as parking lots. The cost of this attitude is high when expressed in terms of traffic congestion and accidents.

In the traffic engineering literature, the safety aspects of parking practices have not been given the same attention as have the operational effects. No widely accepted relationships have been established among

parking configurations (diagonal, flat angle, parallel, etc.), parking density, traffic flow, pedestrian activity and highway safety. The importance of such a measure is emphasized by the large number of accidents involving curb parking. One source has estimated that about 20% of all urban accidents are related to curb parking.(3) Five primary causes were identified:

1. Vehicles parked in the roadway present obstacles and serve to narrow the usable width of the roadway and restrict the flow of traffic. Such parking also restricts right turning movements into and out of side streets, driveways and alleys. Furthermore, parked vehicles may be struck, or their presence may cause sideswipe or rear-end accidents.

2. Vehicles leaving the parked position create a disruption in the traffic flow and, by increasing congestion, lead to rear-end and sideswipe collisions.

3. Vehicles entering the parked position frequently require cars approaching in the lane adjacent to the parking lane to slow or stop. Parking maneuvers are especially hazardous because they usually involve a backing and turning movement. Rear-end and sideswipe collisions can readily result from this maneuver.

4. Drivers or rear-seat passengers getting out of parked vehicles on the street side present an added obstacle in the roadway. Not only are the door and alighting passengers in danger of being struck, but passing traffic may have to swerve or stop suddenly. This produces both rear-end and sideswipe collisions.

5. Reduced sight distance involves pedestrians --many of them children-- attempting to cross the roadway from between parked vehicles, and who may not be seen by the motorist in time to avoid collision. A danger from impaired view also exists when vehicles are parked close to intersections and driveways. Depending on street grades and speeds, curb parking can create a hazardous sight obstruction if allowed on a major route within up to several hundred feet of an egress point.

The Capacity Manual and other traffic engineering manuals state that parallel parking is the preferred arrangement for any on-street parking adjacent to traveled lanes. The angle parking alternative has been typically considered undesirable from a safety and capacity standpoint for the following reasons:

1. Empty parking spaces are hard to detect by the approaching driver, resulting in stop-and-go traffic movement.

2. A driver leaving an angle space has limited visibility to the rear.

3. Through drivers tend to make sudden stops at the slightest indication of back-up movement.

4. Drivers of through vehicles reduce their speed in anticipation of conflict situations.

The belief that safety and capacity are compromised, when diagonal parking is provided, is based on studies from the late 1940's through the 1960's and, to a larger degree, intuitive judgments. However, many early studies of diagonal parking were limited in scope. In particular, "Main Street, U.S.A." was almost universally the type of street where diagonal parking was developed and evaluated. Its use on local urban residential streets presents a different situation than the business street.

The Urban Pedestrian Accident Countermeasures study

concluded that under certain conditions pedestrian behavior could be favorably modified if parallel parking is replaced by diagonal parking.(4) The scanning of oncoming traffic by crossing pedestrians was reported to have increased significantly at locations where diagonal parking replaced parallel parking. Other favorable behavioral changes were also identified and are described in the report.

Diagonal parking spaces also have the benefit of allowing occupants to enter and exit the vehicle from either side without entering the traveled way. This and other findings relative to parking arrangements are documented in a Texas study by Zeigler.(5) This work concluded that flat angle ($22\frac{1}{2}°$) parking did not adversely affect safety and capacity of the travel lane, when compared with parallel parking.

It should be recognized that although parallel parking is generally accepted as preferable to angle layout, there are certain operational disadvantages to this arrangement. The parking maneuver requires a considerable amount of time and therefore disrupts the flow of traffic. Many drivers are not skillful in the parallel parking backing maneuver, thus requiring multiple tries at parking.

Cities do not have funds to provide adequate off-street parking and to eliminate all curb parking. On the other hand, much curb parking should probably be eliminated because of delay to through traffic and hazards to both pedestrians and vehicles. In addition to the Central Business District (CBD) and major roadways, critical areas for parking studies include congested industrial and residential areas. In many instances streets in these areas have been under the sole control of local governments, and parking regulations have often been developed to meet the desires of local pressures. Under current legislation, Federal-aid funds and State funds are being made available for the recently designated routes on the Federal-aid Urban

System and also on off system streets. This will involve the Federal Highway Administration (FHWA) and the States in traffic problems on routes which have previously been under local jurisdiction.

This study was undertaken because of the lack of widely accepted documented data relating to the safety aspects of on-street vehicle parking, the current involvement of the FHWA in reviewing traffic operations on routes other than federally-aided primary and secondary highways, and a general need for an evaluation of curb parking arrangements. The objectives of the study were as follows:

1. To determine the safety and operational characteristics of curb parking alternatives.

2. To develop an unbiased data base relating to these safety and operational characteristics, allowing comparative analyses which consider type of parking, operational characteristics and accident types.

3. To determine appropriate on-street parking arrangements for various geometric, traffic and land use conditions.

The study was organized into four tasks as follows:

Task A - On-Street Parking Literature Review

Task B - Accident Data Collection and Analyses

Task C - Field Tests of Parking Layouts

Task D - Comparison/Trade-off Analyses

The following sections of this report document the work completed on each of these tasks.

CURB PARKING LITERATURE REVIEW

During this study phase, several hundred research reports and technical articles were identified as perhaps relating to the research effort. Sixty-five were deemed to include information of specific value and are abstracted (see Appendix A). Table 1 identifies the reference numbers by five general subject areas, and is followed by a summary of the major findings from the literature review.

Table 1. Identification of Abstracted References by Subject

Subject	Appendix A Reference
Overall parking accidents	1,3,6 through 21, 40
Angle parking accidents	15,17,21 through 28
Pedestrian accidents	4, 29 through 32
Operational studies	2,3,5,12,18,27,28,33 through 47
Curb parking policies	1,8,11,12,16,24,48 through 64

Overall Parking Accidents

Following World War II automobile travel increased rapidly, and pressure to increase the safety and capacity of the street and highway system was being felt by public officials. Early data from a sample of ten large cities found curb parking accidents to represent 5% to 28% of the total accidents.(6) Later data for one of the largest cities found moving vehicles striking parked vehicles to cause 2% of all fatal, 6% of all injury, and 26% of all property damage only type accidents in the city.(13) A smaller community identified 43% of all local and collector street* accidents to involve curb parking.(11) In the same

*Functional classifications are defined on the Definitions page, Appendix B.

city, frequencies of 14 parking accidents per mile were found on major streets, but only 1.8 per mile on local and collector streets.(1)

The picture of curb parking accidents, as related in the 17 reviewed reports, is grim. This type of collision generally represents about one-fifth to one-fourth of urban, non-freeway accidents. A significant proportion of these produce injuries.

Several studies have been reported on the effect of parking prohibitions (removal of parallel type). Accidents were decreased up to 88%.(8,14,18,21,40)

Angle Parking Accidents

Studies in nine Utah cities found changes from angle to parallel layout to reduce parking accidents by 57%, with a 31% overall decrease in injury/fatal type accidents for the study sections.(24) A similar study of two business blocks in Salem, Oregon found a 65% reduction in parking type accidents.

Analysis of accidents in the Abilene, Texas Central Business District (CBD) in the mid-70's showed average accident frequencies per street mile of 5.4 for angle parking versus 1.4 for parallel. When expressed on a rate basis, the angle parking streets had 284 accidents per million vehicle miles, compared with 116 for parallel parking.(28)

The ten reports of angle parking, representing many times this number of studies, were nearly unanimous in finding extremely high frequencies of accidents, as compared with parallel parking. However, adequate data were not identified to distinguish any differences in accident frequency or rate, as a function of varying angles from the curb.

Pedestrian Accidents

Perhaps the most detailed studies ever performed of pedestrian accidents and behavior were reported by Berger

and Knoblauch.[29] Among numerous findings was that 19% involved pedestrians coming from between curb parked vehicles. New York State reported this condition in 8% of pedestrian fatalities and 19% of pedestrian injuries.[30] Another study found 24% of pedestrian accident involvement with "dart-out" from between parked cars.[4] A San Jose study reported a 20% frequency of such accidents, and a Washington, D. C. analysis identified over one-half of all school age child pedestrians killed in traffic, to be stepping from between parked cars.[31,32]

This type of accident would be expected to vary from city to city, due to factors such as density of development and curb parking. In any case, the problem appears to be real. However, one researcher has suggested the use of angle parking along local streets as a counter-measure for pedestrian accidents.[4]

Operational Studies

The fifteen reports on travel speeds, delays and parking-unparking times included findings in auto speed increases of 25% to 47% and transit speed improvements of 3% to 16% as a result of rush hour parking prohibitions.[34] A change from angle to parallel parking at one study location allowed a 36% speed increase.[26]

A study of 37.5 degree angle layout found unparking time to average only 12 seconds, versus a parking time for a parallel arrangement of 32 seconds.[27] Later research confirmed this parallel parking time for 24 foot (7.3 m) marked stalls.[37] This work also involved revision of markings to a tandem skip layout, with 20 foot (6.1 m) stalls separated by 8 foot (2.4 m) maneuver areas. The parking time was reduced to about 21 seconds.

Other studies found curb parking to reduce capacity by 35% in fringe business areas and 45% in central business areas.[39] Street width is a factor, and one source has estimated that parallel parking on both sides of a 2-way street, 45 feet (13.8 m) wide in a central business area, reduces capacity by 90%.[38]

The operational studies tend to agree that about one-half minute is required for the average parallel parking maneuver, that this has a major effect on capacity, and that the parking time can be significantly reduced by use of a skip-dash marking. This is also called a tandem parking or paired parking configuration.

As early as 1950 Monterey Park, California was experimenting with the use of two 20-foot (6.1 m) long parking stalls separated by 11 to 12 feet (3.3 to 3.6 m) of maneuver area between each pair of stalls. About the same time Whittier, California was testing the use of paired 18-foot (5.5 m) long stalls with an 8 foot (2.4 m) maneuver area delineated by red markings. (See Figure 1 for details of typical parking layouts). Since conventional parallel parking arrangements normally allocate 22 to 24 feet (6.7 to 7.3 m) of curb per space, these early tests of paired parking basically involved the redistribution of curb space to provide some reduction in the awkwardness normally associated with conventional back and forth parallel parking maneuvers.

In 1974, Clifton, New Jersey instituted an expanded paired parking arrangement.(45) A maneuvering area of at least 16 feet (4.9 m) is used. The resulting configuration (called the "Travers Tandem") permits a parking vehicle to shift out of the traffic stream in one easy, continuous, forward movement. Parking maneuvers are executed within the parking lane, thus reducing conflicts with moving traffic. The benefits were reported to be dramatic in terms of convenience and avoidance of delay and of benefit to both the individual parker and the overall traffic stream. The parking vehicle is able to clear the traffic lane in about 4 seconds.

A 1971 report challenged the conclusions of many previous studies of angle parking and the assumptions that the safety and delay characteristics applied equally to all angle parking arrangements.(5) The arrangement tested differs from most angle parking in that the spaces were laid out at an angle of 22½° with the curb line as opposed to the more conventional arrangements. This layout has been termed "flat angle" parking. The reported operating

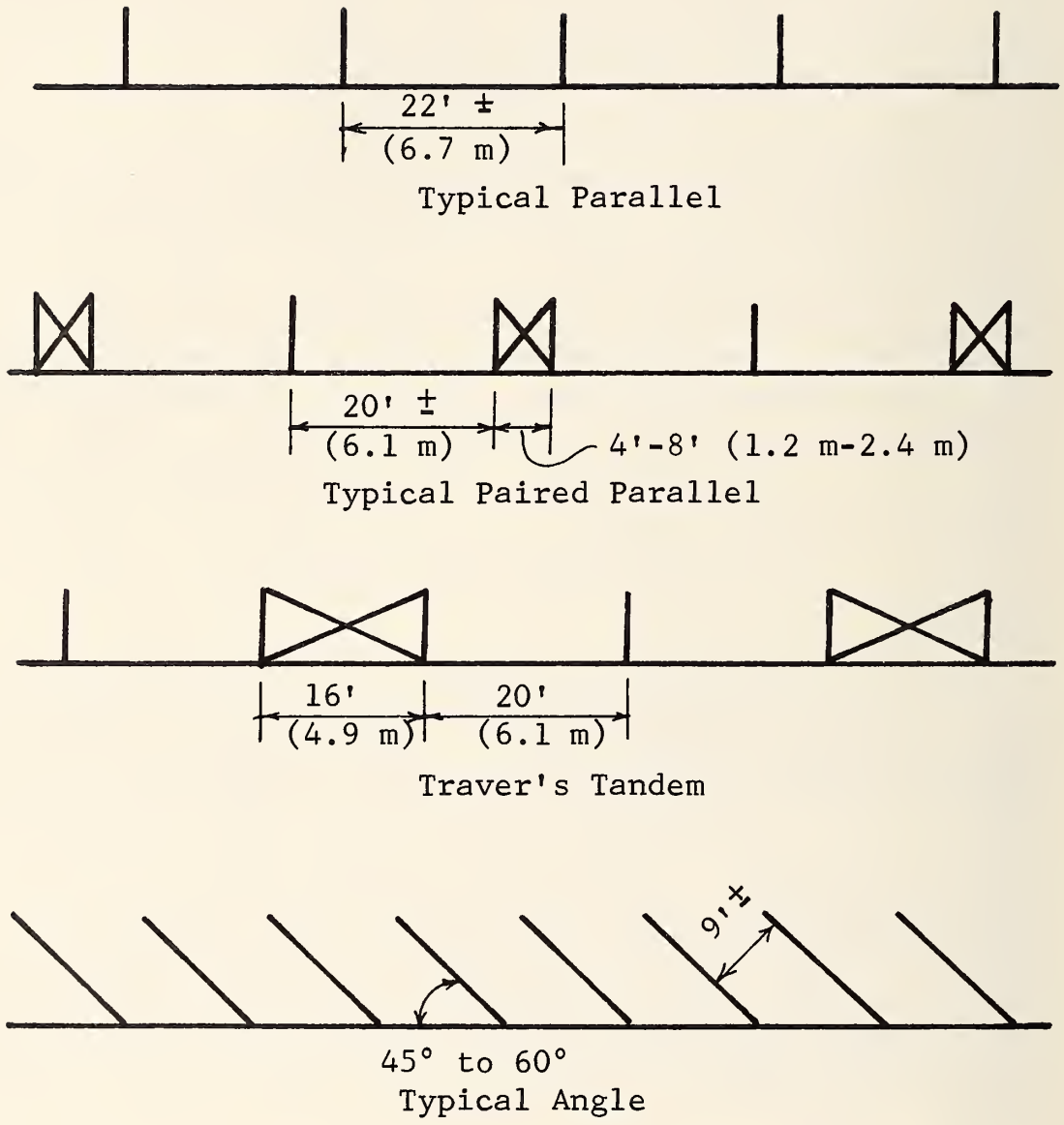


Figure 1. Parking Configurations

experience with this parking layout indicated that it offered advantages over typical angle parking and parallel parking. The following conclusions (among others) were reported:

- Flat angle parking does not adversely affect the safety or capacity of travel lanes when compared with the generally accepted arrangement of parallel parking. This is true, provided that adequate widths for travel lanes are available.

- Flat angle parking results in improved safety for pedestrians entering or leaving parked vehicles.

- Flat angle parking results in less disruption of traffic flow than does parallel parking.

Based on the generally favorable results of their limited testing of flat angle parking in Huntsville, the Texas Highway Department in February 1972 submitted a recommendation that a more extensive evaluation of the advantages and disadvantages of flat angle versus parallel parking be undertaken.

Curb Parking Policies

The literature indicates that while evidence concerning the problems created by curb parking has been accumulating, most cities have been taking steps to encourage or force the development of off-street parking facilities through zoning. Although the ultimate solution to the curb parking problem may be provided through zoning controls, this will take many decades. In the interim, curb parking will continue to exist in commercial and industrial areas, along parts of major street systems, and on practically all local residential streets. In fact, it is impractical not to consider curb parking as a proper function of a local residential street. Even though proper zoning regulations may require two off-street

spaces per dwelling unit, with the availability of up to two additional spaces in the driveways, overflow parking demands by visitors will exist periodically. It is obviously impractical to ask the single family property owner to provide off-street facilities to accommodate occasional overflow demands. At the other extreme, the new apartment, industrial and business development may appropriately be required to provide sufficient off-street facilities to accommodate peak accumulations of all employees, visitors and customers. The degree to which communities choose to regulate and force such complete off-street parking requirements is related to the local problems associated with curb parking and their severity.

In 1950, the American Association of State Highway Officials (AASHO) prepared a summary of state highway department policies on angle and parallel parking.(48) A later AASHO publication recommended that angle parking not be permitted because of its hazard.(64)

In May 1960, the Bureau of Public Roads issued Instructional Memorandum (IM) 21-10-60 titled "Parking Regulations and Control of Traffic on Major Street Projects." The provisions of this IM were intended to apply to all major Federal-aid street projects in urban areas. Application was also deemed desirable to projects in smaller cities and, where pertinent, to highway projects in rural areas where roadside businesses had been or were expected to be developed to the extent that roadside parking would have a significant effect on through traffic. The specific requirements of the IM were as follows:

> Federal-aid major street projects requiring parking regulations generally are those where the present street or right-of-way width is insufficient for the inclusion of parallel parking lanes on one or both sides, and additional width is not attainable or is too costly to acquire. Where sufficient width is available for provision of parallel parking lanes and they are to be included, they should be at least 10 feet (3 m) wide and preferably the full traffic lane width. In severely restricted cases parking lanes only 8

feet (2.4 m) wide may be justified.

> Because of the hazard involved, and because of the greater width of parking lanes required, angle parking adjacent to the through lanes is not to be permitted.

Over a period of years many state highway departments adopted similar policies relating to state funded projects. Typical of many of these policies was "A Guide for Evaluating Parking on Primary Road Extensions" published in March 1967 by the Iowa State Highway Commission.[16] Under this set of guidelines the Commission generally discouraged curb parking due to the adverse effect on traffic flow, increased driver tension and accidents. Angle parking was specifically prohibited adjacent to through traffic lanes because it was reportedly causing up to 50% more accidents than parallel parking. Included in the publication were arrangements for parallel parking and provisions for angle parking physically separated from through traffic by barrier curb channelization.

The curb parking policies of the cities, states and federal goverment, as identified in the literature search, may be summarized as follows:

1. An understanding that high hazard is associated with curb parking in general, and especially with angle parking,

2. Concern for the congestion effect of curb parking,

3. Taking of positive steps to reduce future curb parking demand, by enactment and enforcement of zoning controls requiring off-street parking supply for new developments,

4. Extensive use of rush hour and/or total parking prohibitions,

5. Refusal to allow new angle parking installations, and

6. Limited programs to eliminate existing angle parking, or to convert to parallel type.

CURRENT CURB PARKING PRACTICES

Requests were made of municipalities and states for information regarding their curb parking policies and practices. A total of 205 city traffic engineers were contacted (including 3 metropolitan county traffic engineers), as were the traffic engineers in all 50 states. For uniformity in the replies, similar questions were asked all engineers contacted.

A total of 161 replies were received; 119 from cities in 38 states and 42 from different states. Seven cities and one state responded by letter without specifically responding to the questions. In most cases, these letters provided some of the requested information. In other replies, additional information was appended to the responses.

One primary use made of the contact with cities was in the selection of candidate sites for field studies. Also, a careful analysis of all responses was made to determine current curb parking policies. Because of known policy variations in areas of different land use, information was requested relative to policy in three areas; Retail/Commercial, Industrial and Residential. An analysis of all responses follows. It should be noted that in many cases multiple replies were made, while in other cases no reply was made to a specific question. For this reason, total replies to any one question cannot be equated to the number of responses received.

State Responses

Table 2, Summation of State Responses, shows that 30% to 40% of the states do not allow angle parking at the curb.

Question 4 indicates that about 60% of the states responding have no written policy regarding curb parking. However, comments and/or attachments made it clear that individual state laws provided the direction and authority for parking control, although they were not considered as "written policy." The policy question results should be evaluated with that in mind.

Table 2. Summation of State Responses

	Retail-Commercial	Industrial	Residential
1. Does your State allow angle curb parking along urban routes within your jurisdiction in any of the areas listed? (The term "angle parking" is intended to include parking on the street and in paved areas immediately adjacent to the traffic lanes where the unparking vehicle must normally back into moving traffic.)	a. Yes 27 b. No 12	c. Yes 22 d. No 15	e. Yes 22 f. No 14
2. If angle parking is allowed in any of these areas, what are the permissible angles?	a. 30° 17 b. 45° 22 c. 60° 19 d. 90° 13 e. Other 5	f. 30° 16 g. 45° 19 h. 60° 16 i. 90° 12 j. Other 4	k. 30° 15 l. 45° 19 m. 60° 16 n. 90° 13 o. Other 4
3. If you now allow angle curb parking but have no written policy, what has been the trend in your operations in each of these areas?	a. Remove angle parking 26 b. Make no changes 3 c. Add angle parking 0	d. Remove angle parking 24 e. Make no changes 3 f. Add angle parking 0	g. Remove angle parking 25 h. Make no changes 3 i. Add angle parking 0
4. Does your State have a written policy relating to the use of curb parking in any of the areas listed? (If yes, please attach a copy.)	a. Yes 15 b. No 22	c. Yes 15 d. No 21	e. Yes 15 f. No 22

5. If you have a written curb parking policy, what criteria did you use to establish it?

a. Personal experience 2
b. Prior administrative policy 4
c. Research results 6
d. Other (Please specify) 13 (These responses generally referred to State Laws regarding Parking).

Strong feeling was expressed against angle parking at the curb. The following quotes are typical:

> . . .All angle parking should be eliminated if possible because of the hazardous unparking maneuver and interference with traffic movement.

> . . .A general policy exists discouraging use of angle parking. We also encourage elimination of existing angle parking, if possible.

> . . .Our position generally on angle parking is that it is not in the interest of safety (based on accident experience).

> . . .Diagonal parking is always removed with new construction projects.

In reply to the question on trends in continued use of angle parking, almost all respondents indicated that they were attempting to remove that which exists. None recommended adding such parking.

It was obvious from the 42 state responses that some curb parking could be tolerated, but that angle parking was an operational device that was poorly regarded and one which should not be allowed.

In addition to the personal comments made by many engineers, a few statements or copies of policy were included. Perhaps the most complete was one furnished by the State of New Jersey. A few excerpts follow:

> . . .The disadvantages of angle parking far outweigh the capacity and ease (of parking) factor.

> . . .Accident analysis along roadways where angle parking is being practiced has shown the rate of accidents to be higher in all cases, and in some instances, three times as great as a similar location with parallel parking. . .

> . . .This type of parking (angle parking) is not adaptable for trucks.
>
> . . .Before angle parking is approved . . . the following factors are considered . . .
>
> 1. Road width . . .
> 2. The amount of traffic . . .
> 3. The speed . . .
> 4. The type of vehicles . . .
>
> . . .Another fact that should be considered by municipal officials is that in the event of an accident involving vehicles at a location where angle parking is not approved (by the State), municipal officials could in some way be considered as contributing to the accident.

The State of Wyoming transmitted certain policies, adopted in June 1961, one of which reads as follows:

> The State shall require parallel parking on all streets they maintain.

Taken in context, the intent of this policy statement was that no angle parking would be permitted.

In 1974 the Michigan Department of State Highways and Transportation adopted a policy outlined in their publication, "Uniform Criteria for Major Streets," which prohibits angle parking on all major streets eligible for reimbursement of funds from State Gasoline and Weight taxes. These policies are very restrictive and leave no discretion to cities regarding type of parking allowed on certain streets.

Frequent statements regarding state control of on-street parking were the same as Section 11-1004 (c) of the "Uniform Vehicle Code," published by the National Committee on Uniform Traffic Laws and Ordinances. This paragraph reads as follows:

> Local authorities may by ordinance permit angle parking on any roadway, except that

angle parking shall not be permitted on any Federal-aid or State highway unless the (State highway commission) has determined by resolution or order entered in its minutes that the roadway is of sufficient width to permit angle parking without interfering with the free movement of traffic.

As an example of this policy, Colorado officials indicated that studies were requested in 1968 of all angle parking on their State highways so that justified installations could be officially recognized. To assist in the evaluation and recommendations, the following guidelines were offered:

1. Angle parking should be discouraged where full roadway width (including shoulder or parking area) is less than 70 feet (21.3 m) or where there is any appreciable interference with the free movement of traffic in the travel lanes.

2. Angle parking should be discouraged on any primary highway route or where traffic volume is sufficiently high (over 1000 ADT) to aggravate the problem.

3. Angle parking should be discouraged in a Business District where the speed limit exceeds 25 miles per hour (40 km./hr.), (the basic prima facie limit for such a District).

4. Angle parking should be discouraged where five or more reported accidents of types susceptible of correction by a change to parallel parking have occurred within a 12-month period, each accident involving personal injury or property damage to an apparent extent of $100 or more.

5. Angle parking should be discouraged wherever the diagonal parking stalls are not properly marked or maintained.

6. Angle parking should be discouraged wherever any of the foregoing factors, alone or in

> combination, present strong enough evidence of traffic hazard to outweigh objections of the business community due to a reduced number of available parking places.

Other states submitted criteria or guidelines relative to on-street parking, such as those made available by Indiana (Table 3) and Idaho (Table 4). In addition, Idaho requires a complete supportive study for angle parking approval or deletion which includes parking characteristics, accident history, capacity evaluation and an observation of street operational problems.

One comment from a state official was much more general in nature, as follows:

> As the (street) classification lessens, and we find residential and minor streets of unusual widths, it is more likely that angle parking can be allowed.

However, no specific criteria were given in the response.

Table 3. Parking Criteria According to Various Street Widths* (State of Indiana)

Type Parking	Street Width
No parking either side of street	31.0'
Parallel parking on one side	32.0'
Parallel parking both sides	40.0'
Angle parking one side (45°)	53.0'
Angle parking one side, parallel on the other	61.0'
Angle parking both sides	82.0'
Parallel parking both sides, with lane lines	64.0'
Angle parking both sides, with lane lines	106.0'

*1 foot = 0.3 m.

Table 4. Parking Guidelines for Urban Sections of the State Highway System (State of Idaho)

Curb to Curb Width*	ADT	No. Lanes	Type Parking
Less than 60'	--	--	Parallel or None
60' - 80'	2,000 or less	2	Angle, Parallel or None
	Over 2,000	--	Parallel or None
80' - 100'	8,000 or less	4	Angle, Parallel or None
	Over 8,000	--	Parallel or None

*1 foot = 0.3 m.

City Responses

Table 5 is a summation of replies from the 119 cities. About 40% of the cities reported written curb parking policies. As with the state responses, many cities rely upon state laws and/or city ordinances, which they do not consider as "policy." It was of interest also that only 11 cities reported research results as the basis for any written policies on curb parking. It may well be that the 17 "personal experience" replies include limited local statistics or before-and-after data developed by individuals and not considered "research."

An example of this type of data was furnished by the City of Philadelphia. Traffic accident statistics for that City in 1966 indicated that 35 out of 97 pedestrian fatalities occurred when pedestrians crossed the street between intersections, frequently from between parked vehicles; running into parked vehicles accounted for 54% of noninter-section accidents, and parked car conflicts were involved in 10,916 accidents or almost 26% of the total reported accidents.

Of those allowing angle parking, only a limited number reported a so-called "flat angle" (approximately $22\frac{1}{2}°$). From information available to date, such parking is now operational in a few Texas cities (i.e., Huntsville, Wichita Falls and Abilene) and in two Mississippi cities (Jackson and Gulfport).

Regardless of the number of cities now reporting the use of angle parking, it was very obvious that local traffic engineers are strongly opposed to such parking on the basis of personal experience, accident experience or traffic disruption. Many comments were offered which were of a defensive nature, designed to inform the research staff that even though such parking maneuvers were allowed, they predated the employment of the respondent and that they would have been removed if at all possible. Typical comments are as follows:

> . . . there is, thankfully, but one block in . . . that has back-out angle parking . . .

Table 5. Summation of City Responses

	Retail-Commercial	Industrial	Residential
1. Does your City allow angle curb parking in any of the areas listed? (The term "angle parking" is intended to include parking on the street and in paved areas immediately adjacent to the traffic lanes where the unparking vehicle must normally back into moving traffic.)	a. Yes 72 b. No 39	c. Yes 44 d. No 64	e. Yes 44 f. No 66
2. If angle parking is allowed in any of these areas, what are the permissible angles?	a. 30° 16 b. 45° 37 c. 60° 41 d. 90° 36 e. Other 4	f. 30° 8 g. 45° 23 h. 60° 24 i. 90° 29 j. Other 2	k. 30° 8 i. 45° 20 m. 60° 26 n. 90° 27 o. Other 4
3. If you have angle parking approximately how many curb miles is in place? (The answer is needed in curb miles, i.e. one-half mile on both sides would be one curb mile.)	a. 120 Curb Miles	b. 81 Curb Miles	c. 122 Curb Miles
4. If you now allow angle curb parking but have no written policy, what has been the trend in your operations in each of these areas?	a. Remove angle parking 45 b. Make no changes 24 c. Add angle parking 5	d. Remove angle parking 26 e. Make no changes 22 f. Add angle parking 1	g. Remove angle parking 29 h. Make no changes 23 i. Add angle parking 2
5. Does your City have a written policy relating to the use of curb parking (angle or parallel) in any of the areas listed? (If yes, please attach a copy.)	a. Yes 39 b. No 58	c. Yes 34 d. No 52	e. Yes 36 f. No 53

6. If you have a written curb parking policy, what criteria did you use to establish it?

a. Personal experience 17
b. Prior administrative policy 21
c. Research results 11
d. Other (Please specify) 26 (these responses generally referred to State Law regarding parking.)

Metric Conversion

1 mile = 1.61 kilometers

. . . All angle parking existed when I came here eight years ago. No new angle parking has been installed . . .

. . . Like many areas, some angle curb parking was permitted prior to the City having a knowledgeable traffic engineering function . .

. . . we have a very strong policy against any on-street angle parking . . .

. . . Policy has been to prohibit angle parking . . . except where the City street has been incorporated as part of a parking mall . .

. . . Angle curb parking has not been allowed for over 25 years.

. . . Code allows us to permit angle parking . . . We only do so in industrial areas or dead end streets (no traffic movement).

. . . The existing head-in parking, which has been reduced to date to not more than five city blocks totaled, has been in existence prior to an ordinance passed by the City Council in 1952 prohibiting other than parallel parking. For your information, we feel that any manner of head-in parking which requires backing into the through traffic lanes of a public street for maneuvering is a hazard to traffic flow and safety.

. . . While the City . . . has an ordinance which permits angle parking on streets, at the discretion of the Director of Public Safety, it has been our unwritten policy never to permit such angle parking. This policy is the result of my experience and research over the past 30 years. In my considered opinion, there is no safe way to unpark from street angle parking spaces due to deep penetration into

vehicle travel lanes before adequate sight distance of approaching vehicles may be had.

Other information submitted by cities indicated that at least some limited local studies had been made regarding angle parking in addition to published data. One California city reported a boulevard with a mixture of parallel and angle parking on which:

> . . . The midblock accident rate in the sections where angle parking is allowed is 2.4 times that of those sections where only parallel parking is allowed. The intersection accident rate is approximately the same.

In addition, a Canadian city furnished several years of before-and-after accident data where four blocks of parallel curb parking was converted to angle parking. A brief analysis of the data by this study staff indicated that the small increase in the accident rate was not statistically significant at a level of confidence of 0.95.

None of the submissions of policy, criteria or layouts by city or state agencies included information as to their sources or methods of development, even though this was requested, nor was such information found during the literature review. As a result, the research staff was unable to isolate the development procedures for specific criteria or layouts. It appears that they have indirectly evolved through the years from personal experience and various handbooks.

STREET AND ACCIDENT DATA COLLECTION

A second phase of this project was to determine the magnitude and characteristics of accidents occurring on urban streets, relating these to varying parking configurations, land uses, street widths and street classifications. Street and accident data were gathered from over 170 miles (270 km) of urban streets. A summary of collected data follows. More detailed information is given in Appendix B. General accident findings and statistical analysis is presented in later sections of this report.

Site Selection Criteria

Cities were identified for study on the basis of location-type accident file availability, potential streets for study (having varying widths, land uses and parking angles), and range in city size. Regions of the country were selected to represent different climatic conditions.

Study sites were in five states. Data were collected from ten cities: Miami and Coral Gables, Florida; West Palm Beach, Florida; Clearwater, Florida; Abilene, Texas; Wichita Falls, Texas; Tempe, Arizona; Naperville, Illinois; Skokie, Illinois; and Jackson, Mississippi.

Within each city, specific streets were identified by driving surveys. General development densities of various land uses were noted, plus parking and curb types. Only paved streets were utilized --nearly all of which had curbs. Wherever possible, streets with vertical face curbs of 4-inch to 7-inch (10 cm to 18 cm) heights were selected.

Study streets had generally consistent land use along each side, but some mixtures of different uses on each side were included. Local residential streets having spillover parking from nearby commercial areas were largely avoided. Streets were not studied where known changes in surfacing, pavement or land use occurred during the study time period.

In the residential areas, a balance of property values

was attempted; i.e., both those with older homes and new higher value subdivisions. A mixture of straight and curvilinear local streets was selected to the extent practical in each area. Similarly, the greatest possible range of local street widths was sampled.

Mixtures of cross streets (short blocks) and long streets having primary home frontage were selected. Also included were locations having front driveways for each home versus ones having alley garages.

Areas ranged from those having practically no curb parking to ones having very dense curb parking.

Major routes were selected in terms of varying widths, parking characteristics, land use and traffic volumes. Both 1-way and 2-way streets were included as well as those with and without barrier medians or 2-way left turn lanes.

A significant mileage of major routes with curb parking prohibitions was selected in order to allow an assessment of the types of accidents and rates that are typically observed in the absence of curb parking.

Wherever angle parking was available and proper control conditions existed, studies were made of the various angles to the maximum extent possible.

Coding and Field Measurement

The field inventory sheet and accompanying coding sheet are in Appendix B.

The study sections, called "blocks" on the forms, were composed of segments ranging from a single short city block to as many as a dozen continuous blocks having consistent land use, street width, functional classification and/or traffic volumes, and other characteristics. The street width in each section was measured, and (for most) the number of legal parking spaces on each side was counted by a driving survey. Allowance was made for clearance from driveways, Stop signs and fire hydrants in accordance with local practice in each city and prevailing car size. These

data, plus information on land use, parking regulations, 1-or-2-way traffic flow, and median type, were recorded on the field sheets.

The section lengths were taken from city maps or plat books. Traffic volume data were secured where available and averaged as needed to apply to the mid-year of the accident study period. In all cases, land uses were utilized as a surrogate value for pedestrian traffic counts; i.e., retail, commercial, apartment and single-family residential uses represent descending magnitudes of pedestrian volume (see Appendix B).

Where curb parking stalls were painted, the pertinent dimensions were measured. At a few locations where no curbing existed but the shoulder areas were paved for direct pull off, the distance from the typical bumper line of parked cars to the edge of the traveled way was measured. Such parking exists in many areas, but usually is so irregular, with setback variations occurring every few hundred feet, that no analysis of accident patterns would be meaningful.

Parking Checks

The number of curb parked cars was counted during three time periods on typical weekdays. The mid-morning check was taken between 0900 and 1130 hours, the PM check between 1300 and 1600 hours, and the night check between midnight and 0600 hours. These times were selected to avoid the traffic peak period abnormalities, as well as to obtain the typical overnight parking demand.

From analysis of prior research it was possible to calculate a multiplier factor for residential areas to develop an estimate of the annual space hours of curb parking for each section. Appendix B gives the derivation of this 9.4 factor. The number of vehicles parked in each of the three study periods were summed for each section and multiplied by 9.4 to arrive at the estimated number of daily space hours. This was then multiplied by 360 to pro-

vide an estimate of the annual space hours.*

The annual space hour estimate for retail areas was developed by multiplying each of the three parking check periods by 8 and summing. This was then multiplied by 310 to give an estimate of annual space hours, with allowance for lower parking demands on Sundays and holidays as well as to correct for the longer night period represented by the night check. For example, on some weekdays, retail stores in a given area may close at 1800 hours and on other days remian open until 2100 hours. Thus, the length of "night" parking condition exists for nearly 12 hours instead of 8 hours. It is, of course, conditioned upon the degree to which recreational-oriented curb parking exists as for theaters, bowling alleys, taverns, etc.*

No attempt was made to develop a more rigorous multiplier for retail areas because wide variables would be expected.

Accident Data Criteria and Coding

Two year periods were utilized as a basic minimum for data collection. However, in a few cases where before-and-after conditions were available, only one year was used for each time period.

The tabulation in all cases came directly from police reports, usually in location-type files in the traffic engineer's office. In some cases, original police files were utilized as required. In order to examine the frequency of parking-related intersection accidents as well as midblock and non-parking intersection collisions, data were sampled for all accidents occurring in certain areas. This was done in business areas and for local residential streets.

The accident data tabulation form and code numbers are given in Appendix B.

*More than 2-digit accuracy cannot be presumed; hence 360 rather than 365 as a days-per-year multiplier. In millions, the multiplier for occupancy total, divided by miles, is 0.0025 for retail and 0.0034 for residential areas.

Data Preparation for ADP

Facilities at the University of Tennessee were utilized for cardpunching of all field and accident data. After key punching, all cards were then punch-verified by a separate operator to insure entry integrity.

Card data were subsequently transferred to magnetic disk for ready access in ADP analyses.

Summary of Street Data

Table 6 shows the miles of data collected, by city and type of street. The breakout of mileage for 1-way streets versus 2-way streets, by functional classification (definitions for the classes are listed in Appendix B) is given in Table 7. About one-fourth of the major streets selected were of 1-way operation. Only 6% of the collectors and 2% of the local streets were of 1-way type, in consideration of the lesser mileages of 1-way operation found on such streets across the country.

The mileages for each width, in 2 foot (0.6 m) increments, by functional classification, are given in Appendix Table B-1 (1-way streets) and B-2 (2-way streets). Even though the scheduled collection of only 25 miles (40 km) of major street data was increased to 43 miles (69 km), it was still not possible to collect equal quantities of data for each of the wide variety of widths found in typical American cities. The problem was compounded by necessities for variable land use and parking regulations.

Table 8 shows street miles of data collected by land use as related to functional classification. Most sections were selected having common land uses on both sides of the street. The nine percent of mileage that is related to "all other" principally consists of mixed land uses for which too small a sample was found to utilize in the analysis.

Six general types of parking regulations were isolated. These involve unlimited parking on one or both sides, time limits (such as 1-hour, 2-hour, etc.) on one or both sides,

and prohibited parking on one or both sides. Appendix Table B-3 gives the street miles by these regulations for each functional classification. The percentages of each type were collected to represent regulations typically found for the various street types.

More detailed breakouts by land use for 1-way or 2-way streets and for parking regulations are given in Accident Findings and in Appendix C.

Table 6. Street Miles by Functional Classification and Area

Area	Code	Miles of Streets* Major	Collector	Local	Total
Florida					
Miami, Coral Gables	1	9.73	0	10.75	20.48
West Palm Beach	2	0.67	3.43	6.47	10.57
Clearwater	3	6.74	1.66	11.88	20.28
Texas					
Abilene	4	6.33	2.39	23.12	31.84
Wichita Falls	5	3.92	0.75	8.24	12.91
Arizona					
Tempe	6	0	9.41	5.99	15.40
Illinois					
Naperville	7	1.53	0	7.15	8.68
Skokie	8	8.29	0	22.18	30.47
Mississippi					
Jackson	9	5.87	1.66	12.30	19.83
TOTAL		43.08	19.30	108.08	170.46

* 1 mile = 1.61 kilometers

Table 7. Street Miles* by Directional Flow

Class	1-Way	2-Way	Total
Major	10.70	32.38	43.08
Collector	1.17	18.13	19.30
Local	1.99	106.09	108.08
TOTAL	13.86	156.60	170.46

* 1 mile = 1.61 kilometers

Table 8. Street Miles* by Land Use and Functional Classification

Land Use	Major	Collector	Local	Total	Proportion
Retail only	11.72	0	0.29	12.01	7%
Retail mixed with office, motel or industrial	3.44	0.21	0.17	3.82	2%
Office only	3.97	0.74	0.85	5.56	3%
One-family residential only	11.30	12.80	93.13	117.23	69%
Apartment	2.66	1.37	8.00	12.03	7%
Apartment mixed with one-family	1.79	0.65	2.60	5.04	3%
All other	8.21	3.54	3.04	14.79	9%
TOTAL	43.08	19.30	108.08	170.46	100%

* 1 mile = 1.61 kilometers

ACCIDENT FINDINGS

Summary of Intersection and Midblock Data

A total of 4,804 accidents were tabulated on the inventoried streets of the 10 cities during the respective study periods. Of these, 3,594 were midblock accidents, or those intersection accidents in which curb parking was considered to be a factor (the 5 elements of parking involvement are listed on the accident data code sheet in Appendix Figure B-5). The remaining 1,210 were intersection accidents not involving curb parking and which occurred on selected streets in Miami, Coral Gables, Clearwater and Abilene (City Codes 1, 3 and 4). These were streets in areas where all accident data were tabulated --midblock and intersection, in order to sample the proportion of parking related accidents to total collisions.

Appendix Table B-4 indicates the midblock breakdown by accident severity, street classification and parking involvement, and Table B-5 has the same data for intersection accidents. Table 9 is the sum of these tables.

From these selected area data, over one-half of the midblock property-damage only (PDO) accidents were found to be parking-involved, and nearly one-fourth of the injury type were parking-related. Only 2% of intersection accidents were parking-related. For total accidents (midblock plus intersection) about one-fourth of PDO accidents are parking-related. About 7% of the injury type are parking-related, for an overall average of 20%. This value is in line with previous estimates.(19)

When related to functional classifications, the local streets had 69% of their midblock and 10% of their intersection accidents (a 49% average) parking-involved.

The equivalent figures for collector streets are 86% midblock and 6% intersection, for a 50% average of accidents related to curb parking. Because of these similarities, it is practical to combine local and collector class streets for parking accident analysis.

Table 9. Combined Selected Area Intersection and Midblock Accidents by Severity, Street Classification and Parking Involvement* (2-Way Streets)

Street Class	Severity: PDO Other	PDO Parking Involved	PDO Sub-Total	Injury** Other	Injury** Parking Involved	Injury** Sub-Total	TOTALS Other	TOTALS Parking Involved	TOTAL	Proportion Parking Involved
Local	66	77	143	26	11	37	92	88	180	49%
Collector	26	34	60	12	4	16	38	38	76	50%
Major	1090	257	1347	432	22	453	1522	279	1801	15%
TOTAL	1182	368	1550	470	37	507	1652	405	2057	20%
Proportion Parking Involved		24%			7%			20%		

*Areas where all accidents were tabulated --midblock and intersection.

**One fatal accident recorded, Major street, Other category.

As expected, major streets (having many more conflicts due to driveway and intersection cross traffic) showed quite different proportions of parking-related accidents. The values were 39% for midblock and 2% for intersection, with an average of 15%.

These general findings are important in several ways. Curb parking is shown to be a very pronounced factor in all street accidents of the property damage type. However, only a small proportion of parking accidents along major streets can be directly associated with intersection elements.

Approximately 60% of total reported accidents occurred at intersections, which may be found in a comparison of totals in Appendix Table B-5 and Table 9. This is also consistent with other research findings.(65)

After reviewing these initial data, it was determined that additional intersection accident data would not be coded unless they were parking related. Thus, all accident data and analyses subsequently presented include all midblock accidents plus only those intersection accidents which were considered to be parking related. Table 10 summarizes these data by severity, street classification and parking involvement, for these 3,594 accidents.

Table 10. Accidents by Severity, Street Classification and Parking Involvement*

Street Class	Severity: PDO Other	PDO Parking Involved	PDO Sub-Total	Injury** Other	Injury** Parking Involved	Injury** Sub-Total	TOTALS Other	TOTALS Parking Involved	TOTAL	Proportion Parking Involved
Local	133	396	529	37	37	74	170	433	603	72%
Collector	60	150	210	15	8	23	75	158	233	68%
Major	1094	1229	2323	323	112	435	1417	1341	2758	49%
TOTAL	1287	1775	3062	375	157	532	1662	1932	3594	54%

*All midblock, plus parking-involved intersection accidents.

**One recorded fatal accident --Major street, Other category.

Major Streets

The 43 miles (69 km) of major streets studied were broken down by city code (Table 6), by directional flow (Table 7), by street width (Tables B-1 and B-2), by land use (Table 8), and by parking regulation (Table B-3).

Table 11 provides the breakout of curb mileage by parking regulation for both 2-way and 1-way operation. A significant mileage of major streets with parking prohibitions was studied.

Table 11. Major Street Curb Miles* by Parking Regulation

Parking Regulations	Curb Miles 2-Way	1-Way	Total	Overall Proportion
No Parking	24.56	1.96	26.52	31%
Unlimited	29.65	7.75	37.40	43%
Time Limit	10.56	11.68	22.24	26%
TOTAL	64.77	21.39	86.16	100%

*1 mile = 1.6 km. 1 curb mile = 0.5 street mile.

Table 12 gives a detailed breakout of curb mileage by street width, parking regulation and directional flow. Note that there are many cells that have either a zero or a very small entry. Considering the number of cells, it is apparent that a very large inventory would be required to produce meaningful mileage in each. Furthermore, many street widths may not exist due to design and operational limitations. Thus, it would be impractical to attempt to completely fill a matrix of the detail shown in Table 12.

It can be seen from this table that a substantial length of 2-way major streets was included which had widths between 39 and 44 feet (11.9-13.4 m). Some 25 curb miles (40 km) were in this range, or approximately 39% of the total. Only 4% was 34 feet (10.4 m) wide or less. The 1-way street mileage was more uniformly distributed over a range of widths. A total of nearly 18 curb miles (28 km), or 82% of the total, was between 39 and 56 feet (11.9-17.1 m).

Table 12. Major Street Curb Miles* by Width and Parking Regulations

Width Feet**	2-Way Streets				1-Way Streets				TOTAL
	No Parking	Parking	Time Limit	Sub-Total	No Parking	Parking	Time Limit	Sub-Total	
<=26	0.22	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.22
27-28	1.14	0.0	0.0	1.14	0.94	0.94	0.0	1.88	3.02
29-30	0.86	0.0	0.0	0.86	0.0	0.0	0.0	0.0	0.86
31-32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33-34	0.0	0.58	0.0	0.58	0.11	0.0	0.11	0.22	0.80
35-36	0.21	2.21	0.0	2.42	0.0	0.0	1.06	1.06	3.48
37-38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	3.88	4.44	0.74	9.06	0.45	2.56	0.23	3.24	12.30
41-42	1.62	4.38	0.54	6.54	0.0	0.14	0.42	0.56	7.10
43-44	3.73	5.81	0.26	9.80	0.12	0.0	1.42	1.54	11.34
45-46	0.0	0.0	0.0	0.0	0.14	0.0	0.65	0.79	0.79
47-48	0.23	0.84	0.25	1.32	0.0	0.16	0.70	0.86	2.18
49-50	2.10	0.48	0.28	2.86	0.18	0.92	4.56	5.66	8.52
51-52	0.0	0.16	0.0	0.16	0.0	0.12	0.60	0.72	0.88
53-54	0.54	0.09	0.09	0.72	0.0	0.0	0.0	0.0	0.72
55-56	0.59	2.67	1.81	5.07	0.0	2.92	1.24	4.16	9.23
57-58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59-60	4.37	5.85	0.60	10.82	0.0	0.0	0.0	0.0	10.82
61-62	0.0	0.52	0.0	0.52	0.0	0.0	0.0	0.0	0.52
63-64	0.0	0.22	0.60	0.82	0.0	0.0	0.0	0.0	0.82
65-66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67-68	0.0	0.0	1.28	1.28	0.0	0.0	0.66	0.66	1.94
69-70	5.02	1.14	0.0	6.16	0.0	0.0	0.0	0.0	6.16
71-76	0.06	0.26	2.60	2.92	0.0	0.0	0.0	0.0	2.92
>=77	0.0	0.0	1.50	1.50	0.0	0.0	0.0	0.0	1.50
TOTAL	24.57	29.65	10.55	64.77	1.94	7.76	11.65	21.35	86.12

*1 mile = 1.6 kilometers. **1 foot = 0.3 m.

A tabulation of land use combinations stratified by street width is given in Appendix Tables C-1 (2-way streets) and C-2 (1-way streets). Again, many empty cells are found, and a large quantity of data would be required if significant values were to be obtained in each cell.

The columns in each of these tables represent street segments with land use on both sides considered. For the 2-way streets, 23% had retail development on both sides and 35% had residential development on both sides, while 21% had combined land uses not specifically grouped in any of the seven combinations shown.

Table 13 shows that of the property damage only accidents, 53% involved parking. Of the injury/fatal accidents, 26% involved parking. Overall, nearly one-half of the major street midblock collisions involved parking. The proportion is especially high when considering that nearly one-third of these streets had parking prohibited, and thus practically no parked car accidents.

Tables 14 and 15 show the type of parking involvement stratified by accident type. Several interesting facts appear. First, the 1-way data show a substantially higher parking involvement percentage wise than do the 2-way data. For 1-way streets, 60% of the accidents were parking related, while the value for 2-way streets was only 43%. Of the pedestrian accidents, 21% occurring on 2-way streets involved a sight distance restriction, while only 7% on 1-way facilities involved the same. Overall, only 0.3% of all accidents were identified to involve a restricted sight distance caused by curb parking. This was much lower than expected and appeared different from many reports annotated in the parking literature review.[4,29-32] However, these studies tended to express the percent of pedestrian accidents involving parked cars, rather than the percent of total accidents involving pedestrians coming from between parked cars and having a sight distance problem.

Table 13. Major Street Midblock Accidents by Severity, Parking Involvement and Street Operation

Street Operation	Severity: PDO Other	PDO Parking Involved	PDO Sub-Total	Injury* Other	Injury* Parking Involved	Injury* Sub-Total	TOTALS Other	TOTALS Parking Involved	TOTAL
2-Way	798	700	1498	238	75	313	1036	775	1811
1-Way	296	529	825	85	37	121	381	566	947
TOTAL	1094	1229	2323	323	112	435	1417	1341	2758
Proportion Parking Involved		53%			26%			48%	

*Only 1 fatal accident recorded (1-Way, Other category).

Table 14. Major Street Midblock Accidents by Type and Parking Involvement (2-Way)

Type of Parking Involvement	Accident Type: Vehicle-Vehicle on-street	Vehicle-Vehicle at driveway	Vehicle-Fixed Object	Vehicle-Parked Car	Vehicle-Pedestrian	Vehicle-Bicycle	Miscellaneous	TOTAL
No Parking Involvement	518	315	154	0	24	9	16	1036
Open Door	1	0	0	59	0	1	0	61
Parking	6	1	3	73	2	0	0	85
Sight Restricted	0	2	1	0	8	0	0	11
Stationary	11	5	1	357	2	0	0	376
Unparking	8	6	4	222	2	0	0	242
Subtotal parking	26	14	9	711	14	1	0	775
TOTAL	544	329	163	711	38	10	16	1811
Proportion Parking Involved	4.7%	4.2%	5.5%	100%	36.8%	10%	0%	43%

Table 15. Major Street Midblock Accidents by Type and Parking Involvement (1-Way)

Type of Parking Involvement	Accident Type: Vehicle-Vehicle on-street	Vehicle-Vehicle at driveway	Vehicle-Fixed Object	Vehicle-Parked Car	Vehicle-Pedestrian	Vehicle-Bicycle	Miscellaneous	TOTAL
No Parking Involvement	241	93	32	0	11	3	0	380
Open Door	0	0	1	19	0	0	0	20
Parking	3	0	4	67	0	0	0	74
Sight Restricted	0	1	0	0	1	0	0	2
Stationary	3	2	0	264	0	0	3	272
Unparking	6	0	2	189	2	0	0	199
Subtotal parking	12	3	7	539	3	0	3	567
TOTAL	253	96	39	539	14	3	3	947
Proportion Parking Involved	4.7%	3.1%	17.9%	100%	21.4%	0%	100%	60%

The 2-way and 1-way street accidents were also related to the total number of accidents tabulated for each type of operation. This comparison is given in Table 16.

Table 16. Parking Accident Type by 2-Way and 1-Way Streets

Type of Accident	Proportion of Total Accidents 2-Way Streets	1-Way Streets
Open door	3.4%	2.1%
Maneuver to park	4.7%	7.8%
Stationary parked car	20.8%	28.6%
Maneuver to unpark	13.4%	21.0%

The largest difference appears in the unparking category, however no one accident type appears to clearly stand out as the basic cause of the higher 1-way street proportion of parking accidents.

The higher proportion of door opening accidents on the 2-way streets might be expected because low vehicle occupancy rates result in the driver's side door being opened more often than the passenger side, and of course the driver of a left side of street parked car is not exposed to direct conflict.

The vehicle-vehicle, on-street parking accident (caused by sudden swerves or stops) was low, as was parking-involved driveway, fixed-object or bicycle accidents. Overall, less than 3% of total accidents fell into these categories.

The stationary parked car accounts for 23% of all major street midblock accidents, with the unparking maneuver causing the second largest group with 16%. The next categories are the parking maneuver (representing 6%) and the door opening (averaging 3%).

Data on non-parking accidents may also be extracted from the study. Of the midblock accidents, 15% involved driveways; a value consistent with several prior studies.(66) Fixed object collisions accounted for 7%.

Collector Streets

For the 19 miles (31 km) of collector streets, data given in Table 6 showed this mileage by city code, and directional flow was broken down by street widths in Tables B-1 and B-2. Table 8 showed a breakdown by land use and Table B-3 a breakdown by parking regulation.

In this section, additional tables are presented giving more specific details of the collector street mileage. Table 17 provides information by parking regulation for 2-way and 1-way streets. Only small proportions were sampled with prohibited or time limit parking, because these restrictions occur infrequently on collector streets.

Table 17. Collector Street Curb Miles* by Parking Regulation

Parking Regulation	Curb Miles 2-Way	Curb Miles 1-Way	Total	Overall Proportion
No Parking	1.92	0.39	2.31	6%
Unlimited	32.73	0.79	33.52	87%
Time Limit	1.62	1.17	2.79	7%
Total	36.27	2.35	38.62	100%

*1 mile = 1.6 km
1 curb mile = 0.5 street mile.

A further breakdown of 2-way and 1-way street mileage is provided in Table 18. This table shows the parking regulations encounted by width of street, again in 2-foot (0.6 m) increments. The matrix shown in the table has only thirty cells with data out of a total of ninety. Of these thirty data points, only six had a mileage greater than 1.0 (1.6 km). This again illustrates that substantial data were not available across all ranges of variables considered in this study.

Table 18. Collector Street Curb Miles* by Width, Directional Operation, and Parking Regulations

Width Feet**	Parking Regulations								
	2-Way Streets				1-Way Streets				
	No Parking	Parking	Time Limit	Sub-Total	No Parking	Parking	Time Limit	Sub-Total	TOTAL
<=20	0.16	0.16	0.0	0.32	0.0	0.0	0.0	0.0	0.32
21-22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-28	0.11	0.31	0.0	0.42	0.0	0.10	0.10	0.20	0.62
29-30	0.0	1.76	0.0	1.76	0.0	0.0	0.0	0.0	1.76
31-32	0.0	0.30	0.0	0.30	0.0	0.0	0.0	0.0	0.30
33-34	0.21	0.36	0.11	0.68	0.0	0.0	0.0	0.0	0.68
35-36	0.0	3.48	0.0	3.48	0.0	0.0	0.18	0.18	3.66
37-38	0.0	0.40	0.0	0.40	0.0	0.0	0.0	0.0	0.40
39-40	1.05	15.85	0.78	17.68	0.31	0.40	0.67	1.38	19.06
41-42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.09	1.31	0.20	1.60	0.0	0.0	0.0	0.0	1.60
45-46	0.0	0.28	0.0	0.28	0.0	0.0	0.0	0.0	0.28
>=47	0.31	8.61	0.53	9.45	0.08	0.28	0.20	0.56	10.01
Total	1.93	32.82	1.62	36.37	0.39	0.78	1.15	2.32	38.69

*1 mile = 1.6 kilometers 1 curb mile = 0.5 street mile

**1 foot = 0.3 m.

A substantial attempt was made to obtain an appropriate range of data variables. It can be seen that 49% of 2-way streets were in the 39 to 40 foot (11.9 to 12.2 m) width category. Additional mileage of 9% was in the 35 to 38 foot (10.7 to 11.6 m) category. Furthermore, approximately 59% of the 1-way mileage was in the 39 to 40 foot (11.9 to 12.2 m) category. These limited ranges are to be expected, because nationally recommended widths for collector streets are 36 to 40 feet.(59)

Two-way and 1-way street mileage broken down by width and land use are presented in Appendix Tables C-3 and C-4. The land use tabulations consider combinations utilizing both sides of the street. Over two-thirds of the collector street mileage had residential land use on both sides, while none had retail on both sides.

Table 19 gives collector street accident breakdowns by severity, 2-way and 1-way operations, and parking involvement. It shows that 210 (90%) of the 233 total accidents involved property damage only. Over two-thirds of the accidents involved parking (as compared to about one-half on the major streets).

Further breakdowns of the data by accident and type of parking involvement are presented in Tables 20 and 21. None of the total midblock accidents involved a pedestrian with a parked car sight restriction. About 2% of the accidents involved pedestrians. Overall, no significant difference appears between the 2-way and 1-way street operation.

Overall, only 3% of total on-street vehicle-vehicle, driveway, fixed object or bicycle accidents were related to parking. A stationary parked car was struck in 50% of all accidents, while unparking maneuvers were involved with 13% of accidents.

Table 19. Collector Street Midblock Accidents by Severity, Parking Involvement and Street Operation

Street Operation	Severity: PDO Other	PDO Parking Involved	PDO Sub-Total	Injury* Other	Injury* Parking Involved	Injury* Sub-Total	TOTALS Other	TOTALS Parking Involved	TOTAL
2-Way	47	102	149	12	7	19	59	109	168
1-Way	13	48	61	3	1	4	16	49	65
TOTAL	60	150	210	15	8	23	75	158	233
Proportion Parking Involved		71%			35%			68%	

*No fatal accidents recorded.

Table 20. Collector Street Midblock Accidents by Type and Parking Involvement (2-Way)

Type of Parking Involvement	Accident Type: Vehicle-Vehicle on-street	Vehicle-Vehicle at driveway	Vehicle-Fixed Object	Vehicle-Parked Car	Vehicle-Pedestrian	Vehicle-Bicycle	Miscellaneous	TOTAL	Proportion (%)
No Parking Involvement	16	26	14	0	2	0	1	59	35
Open Door	0	0	0	1	0	0	0	1	1
Parking	0	0	0	2	0	0	0	2	1
Sight Restricted	0	0	0	0	0	0	0	0	0
Stationary	1	1	2	81	0	0	0	85	50
Unparking	0	0	1	20	0	0	0	21	13
Subtotal Parking	1	1	3	104	0	0	0	109	65
TOTAL	17	27	17	104	2	0	1	168	100
Parking Proportion	6%	4%	18%	100%	0	0	0	65%	

Table 21. Collector Street Midblock Accidents by Type and Parking Involvement (1-Way)

Type of Parking Involvement	Accident Type: Vehicle-Vehicle on-street	Vehicle-Vehicle at driveway	Vehicle-Fixed Object	Vehicle-Parked Car	Vehicle-Pedestrian	Vehicle-Bicycle	Miscellaneous	TOTAL	Proportion (%)
No Parking Involvement	5	6	4	0	1	0	0	16	25
Open Door	0	0	0	0	0	0	0	0	0
Parking	0	0	2	5	0	0	0	7	11
Sight Restricted	0	0	0	0	0	0	0	0	0
Stationary	0	0	0	31	1	0	0	32	49
Unparking	1	0	0	9	0	0	0	10	15
Subtotal Parking	1	0	2	45	1	0	0	49	75
TOTAL	6	6	6	45	2	0	0	65	100
Parking Proportion	17%	0	33%	100%	50%	0	0	75%	

Local Streets

A large portion of the overall mileage of streets considered in this study were of local type, being 108 miles (174 km), or over 63% of the total. While two and one-half times as much local street mileage was studied when compared to major streets, only about one-sixth as many accidents were reported. This is not unexpected, considering traffic volumes for the respective classes of streets, but it does point out the necessity of larger sample sizes for streets with lower exposures.

Most of the local street mileage was 2-way. As was shown in Table 7, only 2 miles (3.20 km) was 1-way, compared with 106 miles (170 km) of 2-way. This is probably representative of the situation nationally, with the use of 1-way local streets restricted to locations with special characteristics. These directional flow mileages were stratified by street widths in Appendix Tables B-1 and B-2, while Table 8 gave a breakdown of the total street mileage by parking regulation, with 102 miles (164 km) shown to have unlimited parking.

Table 22 shows 2-way and 1-way curb mileage by width and parking regulation. While the second part of this table has few entries (due to limited 1-way mileage), a fairly good dispersion of 2-way street mileage is given by parking regulation over the street width range. Very substantial mileages were obtained for almost all width groups between 23 and 40 feet (7.0 and 12.2 m). This is consistent with the national standards for local street widths, ranging from 22 to 36 feet (6.6 to 11.0 m).[59]

Land use tabulations by width are presented in Appendix Table C-5 for 2-way streets. (The limited 1-way data do not warrant such a listing). The predominant local street land use was residential (one-family) on both sides, with 88% in this category. This was selected to reflect the large amount of residential local street mileage typically found across the nation. Also, the low mileage with office and retail land use on both sides reflects the low usage of these street types for that particular land use.

Table 22. Local Street Curb Miles* by Width and Parking Regulations

Width	Parking Regulations								TOTAL
	2-Way Streets				1-Way Streets				
	No Parking	Parking	Time Limit	Sub-Total	No Parking	Parking	Time Limit	Sub-Total	
<=20	1.79	6.88	0.0	8.67	0.0	0.0	0.0	0.0	8.67
21-22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-24	0.45	19.90	0.22	20.57	0.0	0.0	0.0	0.0	20.57
25-26	0.17	12.61	0.0	12.78	0.0	0.0	0.0	0.0	12.78
27-28	0.42	21.22	0.0	21.64	0.0	3.54	0.0	3.54	25.18
29-30	1.22	28.50	0.06	29.78	0.0	0.0	0.0	0.0	29.78
31-32	0.0	23.06	0.0	23.06	0.0	0.0	0.0	0.0	23.06
33-34	0.0	22.08	0.0	22.08	0.0	0.44	0.0	0.44	22.52
35-36	0.09	35.63	0.71	36.43	0.0	0.0	0.0	0.0	36.43
37-38	0.0	1.16	0.0	1.16	0.0	0.0	0.0	0.0	1.16
39-40	0.12	25.90	1.18	27.20	0.0	0.0	0.0	0.0	27.20
41-42	0.0	1.00	0.0	1.00	0.0	0.0	0.0	0.0	1.00
43-44	0.0	1.28	0.50	1.78	0.0	0.0	0.0	0.0	1.78
45-46	0.0	3.98	0.0	3.98	0.0	0.0	0.0	0.0	3.98
>=47	0.50	0.79	0.77	2.06	0.0	0.0	0.0	0.0	2.06
TOTALS	4.76	203.99	3.44	212.19	0.0	3.98	0.0	3.98	216.17

*1 mile = 1.6 kilometers. 1 curb mile = 0.5 street mile.

Accident severity tabulations by type of street operations are shown in Table 23 for the 603 reported local street accidents. Property damage only (PDO) accidents accounted for 88%. This compares with 84% on major streets and 90% on collector streets. Thus, PDO accidents were found to form a uniform portion of the total accident data for all street classifications.

Of the local street accidents, 433 involved parking in some way. This constitutes a 72% parking involvement, considerably more than the 49% reported for major streets, but little different from the two-thirds reported for collectors. It is also important to note that one-half of the injury accidents have parking involvement.

Accident type by parking involvement data are presented in Tables 24 and 25. For 2-way streets, it can be seen that 61% involved a vehicle striking a stationary parked car. Thirteen percent involved a sight restriction due to a parked car, 12 of these being pedestrian accidents and 1 involving a bicyclist.

For the 1-way local streets, 7 of the 8 reported accidents were pedestrian involved. This appears to be a rather high number, probably over-representing the proportion of pedestrian accidents usually found on this type of facility.

Considering all local streets, nearly 5% of the midblock accidents were found to involve pedestrians. Because of the limited mileage of 1-way streets, no significant differences can be identified, as compared with 2-way operation.

Overall, only 1% of total local street midblock moving vehicle-vehicle, driveway, fixed object or bicycle accidents were related to parking. A stationary parked car was struck in 61% of total accidents, while unparking maneuvers were involved with only 6%.

Unlike major streets, and to a degree collector streets, the local streets are not volume dependent. Because most cities have only very limited annual average daily traffic data for local streets, any comparative volume-dependent rates would be difficult to compute.

Table 23. Local Street Midblock Accidents by Severity, Parking Involvement and Street Operation

Street Operation	Severity: PDO Other	PDO Parking Involved	PDO Sub-Total	Injury* Other	Injury* Parking Involved	Injury* Sub-Total	TOTALS Other	TOTALS Parking Involved	TOTAL
2-Way	132	389	521	37	37	74	169	426	595
1-Way	1	7	8	0	0	0	1	7	8
TOTAL	133	396	529	37	37	74	170	433	603
Parking Proportion Involved		75%			50%			72%	

*No reported fatal accidents.

Table 24. Local Street Midblock Accidents by Type and Parking Involvement (2-Way)

Type of Parking Involvement	Accident Type: Vehicle-Vehicle on-street	Vehicle-Vehicle at driveway	Vehicle-Fixed Object	Vehicle-Parked Car	Vehicle-Pedestrian	Vehicle-Bicycle	Miscellaneous	TOTAL	Proportion (%)
No Parking Involvement	28	80	40	0	8	3	10	169	28
Open Door	0	0	0	5	0	0	0	5	1
Parking	1	0	1	9	0	0	0	11	2
Sight Restricted	0	0	0	0	12	1	0	13	2
Stationary	1	3	1	355	1	0	1	362	61
Unparking	0	0	1	34	0	0	0	35	6
Subtotal Parking	2	3	3	403	13	1	1	426	72
TOTAL	30	83	43	403	21	4	11	595	100
Parking Proportion Involved	7%	4%	7%	100%	62%	25%	9%	72%	

Table 25. Local Street Midblock Accidents by Type and Parking Involvement (1-Way)

Type of Parking Involvement	Accident Type: Vehicle-Vehicle on-street	Vehicle-Vehicle at driveway	Vehicle-Fixed Object	Vehicle-Parked Car	Vehicle-Pedestrian	Vehicle-Bicycle	Miscellaneous	TOTAL	Proportion (%)
No Parking Involvement	1	0	0	0	0	0	0	1	13
Open Door	0	0	0	0	1	0	0	1	13
Parking	0	0	0	0	0	0	0	0	0
Sight Restricted	0	0	0	0	0	0	0	0	0
Stationary	0	0	0	0	6	0	0	6	74
Unparking	0	0	0	0	0	0	0	0	0
Subtotal Parking	0	0	0	0	7	0	0	7	87
TOTAL	1	0	0	0	7	0	0	8	100
Parking Proportion Involved	0%	0%	0%	0%	100%	0%	0%	87%	

The accident tables presented in the remainder of this section all have as one of the variables street width. These are grouped in 2-foot (0.6 m) classes, with all less than 21 feet (6.4 m) combined, as are all over 46 feet (14.0 m).

Two-way and 1-way data are combined in Table 26, which gives accident frequencies by street width and land use. Considering that these are not volume-dependent and may reflect very limited exposure due to short study lengths in a given width group, the uniformity for one-family residential land use is rather remarkable. They range between 1.0 and 2.6 accidents per mile per year (1.6 - 4.2 accidents per km. per year) for all widths except those over 44 feet (13.4 m). On the other hand, relatively high frequencies are noted for apartment areas on streets between 27 feet (8.2 m) and 34 feet (10.4m) wide. These frequencies were not so uniform, but are several orders of magnitude greater than those in the residential areas. The reason for this may be one (or more) of several possibilities, among which are higher volumes (thus higher exposures), more pedestrian activity, or higher on-street parking utilization.

Table 27 gives combined use accident frequency by street width. Since no streets were inventoried for this study which utilized angle parking on both sides, the only frequencies shown are for parallel parking. Far less variation in accident frequency is found, due to the weighting by large lengths of streets having one-family residential land usage.

A tendency appears for low accident frequencies in the very narrow widths, reaching a peak in the range of 27 to 34 feet (8.2 m to 10.4 m), which includes actual and nationally recommended sizes of most local streets. A general decrease in rates then appears with greater widths, however accident and mileage samples are mostly quite small.

Table 28 compares width and parking occupancy, and presents combined data from 2-way and 1-way streets. The average number of parked cars for each period checked (AM, PM and night) was determined, then divided by the estimated number of parking spaces. The result was called "percent occupancy".

Table 26. Local Street Midblock Accident Frequency per Mile* per Year by Street Width and Land Use

Width Feet**	Retail (Both Sides)	Office (Both Sides)	Motel (Both Sides)	1-Family Residential (Both Sides)	Apartments (Both Sides)	Retail Mixed Office, Motel, Industrial	1-Family Residential, Apartments	All Other
< =20				2.0				
21-22								
23-24				1.4				2.9
25-26				1.2	2.0			
27-28			2.2	2.6	12.9		12.6	0
29-30		1.5	0	2.4	20.3			0
31-32			0	2.0	11.2			
33-34				1.5	11.4		23.1	
35-36	20.9	8.8		2.5	3.9		2.8	3.4
37-38			2.0	1.5				0
39-40	13.2	6.0		1.0	2.2		3.4	0.5
41-42				2.0				
43-44		0		1.3				
45-46				0.4				
> =47	0	17.2		8.8	9.7	14.5	0	3.3

*One mile = 1.6 kilometers. **One foot = 0.3 meters.

NOTE: Cells with no entries indicate no data available for that particular cell. Zero entries indicate study section included in data, but no recorded accidents.

Table 27. Local Street Midblock Accident Frequencies per Mile* per Year by Street Width

(only streets w/unlimited parallel parking)

Width Feet**	No. Study Sections	No. Miles	Number Accidents	Accident Frequency
<=20	22	2.55	11	1.4
21-22				
23-24	52	9.62	39	1.6
25-26	22	6.22	19	1.2
27-28	69	9.23	63	5.2
29-30	46	13.48	103	3.7
31-32	35	11.53	85	4.1
33-34	47	10.91	60	3.3
35-36	60	16.98	96	2.8
37-38	3	0.49	2	1.6
39-40	62	12.95	31	1.1
41-42	1	0.50	3	2.0
43-44	2	0.64	4	1.3
45-46	26	1.93	5	0.4
>=47	3	0.17	1	2.9
Total (Avg.)	450	97.20	522	2.7

*One mile = 1.6 kilometers.

**One foot = 0.3 meters.

NOTE: Cells with no entries indicate no data available for that particular cell.

Table 28. Local Street Midblock Accident Frequency per Mile* per Year by Street Width and Parking Occupancy (only streets with parking allowed)

WIDTH FEET**	PERCENT OCCUPANCY															
	0-10				11-30				31-50				51-100			
	NO. STUDY SECTIONS	NUMBER MILES	NUMBER ACCIDENTS	ACCIDENT FREQUENCY	NO. STUDY SECTIONS	NUMBER MILES	NUMBER ACCIDENTS	ACCIDENT FREQUENCY	NO. STUDY SECTIONS	NUMBER MILES	NUMBER ACCIDENTS	ACCIDENT FREQUENCY	NO. STUDY SECTIONS	NUMBER MILES	NUMBER ACCIDENTS	ACCIDENT FREQUENCY
<=20	18	1.94	8	1.2	3	0.33	3	3.1								
21-22																
23-24	46	8.70	36	1.6	4	0.75	1	0.4	1	0.06	1	5.9				
25-26	13	4.40	11	1.0	7	1.46	6	1.7	1	0.13	0	0				
27-28	13	3.26	13	1.1	21	2.05	8	1.7	28	2.89	27	6.3	18	1.80	24	8.7
29-30	16	5.96	30	2.0	25	6.59	51	2.7	2	0.22	1	1.8	4	0.57	17	15.2
31-32	3	0.94	2	1.1	18	7.29	27	1.8	2	0.30	7	10.1	6	1.44	37	11.8
33-34	7	0.76	1	1.4	12	2.34	7	1.4	15	4.06	21	2.4	8	1.56	24	10.7
35-36	19	5.84	27	2.3	32	10.01	56	2.6	8	1.32	6	3.0	8	0.95	17	6.8
37-38					1	0.17	1	2.0	1	0.09	0	0				
39-40	17	3.84	8	0.5	27	4.67	21	2.4	7	0.55	4	2.2				
41-42																
43-44									2	0.25	0	0	1	0.13	0	0
45-46	17	0.96	0	0	6	0.31	0	0	2	0.19	2	3.9	1	0.06	0	0
>=47	1	0.06	0	0	3	0.20	8	12.3	4	0.32	5	7.5	2	0.20	3	7.9
TOTAL (AVG.)	170	36.66	136	1.3	159	36.17	189	2.2	73	10.38	74	4.4	48	6.71	122	9.3

*1 mile = 1.6 kilometers

**1 foot = 0.3 m

Each accident frequency in Table 28 represents an average for the number of study sections shown. In other words, a frequency was computed for each section in a given street width group and occupancy, then averaged across all frequency values.

Over 36 miles (58 km) are included in both the 0-10% and 11-30% occupancy groups, while over 10 miles (16 km) is in the 31-50% group and nearly 7 miles (11 km) is in the group with over 50% occupancy. Thus, a total of about 73 miles (117 km) or 67% of the local street mileage had a parking utilization as expressed by percent occupancy of 30 or less. It is of interest to observe that the accident frequencies increase with occupancy. The frequency for the over 50% occupancy group is seven times greater than for the lowest occupancy group.

Summary

The general accident findings may be summarized in several areas. First is the very high proportion of midblock accidents involving parking (49% for major streets, 68% for collectors and 72% for local streets).

Of the injury or fatal midblock accidents, the proportion found to be involved with parking is 26% on major streets, 25% on collectors, and 50% on local streets.

About 0.6% of total major street midblock accidents involved pedestrians struck while emerging from behind a parked vehicle. For collector streets, none was found, but on local streets the proportion was 3%. Overall, 1% of midblock accidents were of parking-related pedestrian type.

The only difference identified between 2-way and 1-way operation concerned major streets. The latter had a substantially greater proportion of midblock accidents as parking related (60% versus 43% for 2-way streets). The greatest difference occurred with the unparking maneuver. This is possibly affected by restricted driver sight distance to the right rear, when leaving stalls on the left

side of the 1-way street. The maneuver to park also had a much higher accident proportion on 1-way streets. Only one category of parked car accidents had a higher percentage on 2-way streets --the door opening collision. However, this category accounted for only 2% to 3% of total midblock accidents.

Comparisons among the three street classes show stationary parked car accidents, as a proportion of total accidents, to be 23% for major streets, 50% for collectors and 61% for local streets. For the next ranking, unparking maneuver, the respective percentages were 16, 13 and 6. As would be expected, the "action-related" parking maneuver accidents decline in significance as volumes decline.

A comparison of local street annual accidents per mile shows that increased percents of parking occupancy result in greatly increased accident frequencies.

STATISTICAL ANALYSIS

Description of Classification Variables

In order to make comparisons between different locations, the street condition was defined by each of the following factors:

1. Street Classification
2. Parking Arrangement
3. Land Use
4. Parking Utilization

The functional classifications described in previous sections (major, collector or local) were utilized. Data from these groups were analyzed separately.

Parking arrangements were grouped into six conditions: no parking, parallel parking, parallel parking with neutral zones (skips), 22½° angle parking, 30° angle parking and high angle parking (combining both 45° and 60° angle parking). Because different parking conditions could occur on opposite sides of a street, 15 combinations of these six parking conditions were found in the data.

The land uses that were explicitly chosen for study were: retail, office, single family residential, apartments, motel, industrial, and school/park. Due to limited samples, the last three types were combined into a 'miscellaneous' category. In all, there were 15 combinations of these five types.

Parking utilization was measured by using the annual space hours per mile for each study location. These were calculated as described in Appendix B. To allow for sampling error, and to simplify the analysis, utilization values were divided into four levels:

Annual Space Hours Occupied per Mile* (millions)	Parking Utilization Level
0 to 0.1	very low
0.1 to 0.5	low
0.5 to 1.0	moderate
over 1.0	high

Combining the groups of streets, parking, land use, and parking utilization results in some 2,700 potential configurations. Since this is approximately three times the number of study locations, many were not found. Appendix Tables D-1 through D-3 give the combinations present in the data.

Additional factors were originally considered for use in the analysis. These included average daily traffic, width of street, driving width, 1-way or 2-way flow, and length of study (in mile-years) for each location. Except for traffic volume, there was no discernable relationship between these factors and the accident rate, thus they were excluded from the analysis.

Response Variables

The response variable originally used with major and collector streets was accidents per million vehicle miles (acc/MVM). Due to lack of traffic counts for local streets, the response variable originally used for these streets was accidents per mile per year (acc/MY).

There were two anomalies with these response variables that must be noted. The first was present in both acc/MVM and acc/MY and is characteristic of accident data in general. This consisted of a proportionality between the mean and the variance of accident rate sets. That is, if there are two groups (such as A and B) for which the accident rate was measured, and A had a higher average accident rate than B, then A also had a greater variation among the individual location accident rates than B. This anomaly traditionally requires a transformation upon the response variable. The

*1 mile = 1.6 kilometers

description of the transformation and the rationale behind it is given in Appendix D.

The second anomaly occurred only with the acc/MVM values. For locations with less than 5,000 ADT, both the minimum and the maximum accident rates increased as ADT dropped. For those locations with over 5,000 ADT, both the minimum and the maximum accident rates were constant as ADT increased. In other words, as volume increases, the accident rate band sloped downward to about 5,000 ADT, and then became constant. This problem occurred in both the raw and the transformed rates. This suggests that acc/MVM cannot be used across all ADT levels for comparison between different locations.

Analysis Procedure

After transforming the response variable, the data were separated according to street classification and each portion analyzed.

First, those specific comparisons between levels of one factor which could be made while holding the other factors constant were identified. Then, by using an analysis of variance (ANOVA) upon different street configurations, these specific comparisons were examined for significance using a Bonferroni procedure. Following this, a Scheffe' post-hoc analysis was performed to look for general patterns of differences between the street configurations. A brief description of these procedures is given in Appendix D.

Major Street Analysis

Parking Utilization

The factor showing the greatest effect upon the accident rate was the parking utilization level. All pair-wise comparisons between the four levels of utilization showed differences significant at the 0.025 level. A summary of these comparisons in given in Table 29.

Table 29. Comparisons for Parking Utilization Levels on Major Streets

Annual Space Hours per Mile (Millions)			Number of Locations
0 to 0.1	vs	0.1 to 0.5	18 vs 18
0 to 0.1	vs	0.5 to 1.0	2 vs 20
0 to 0.1	vs	1.0 up	9 vs 31
0.1 to 0.5	vs	0.5 to 1.0	11 vs 29
0.1 to 0.5	vs	1.0 up	12 vs 36
0.5 to 1.0	vs	1.0 up	44 vs 45

1 mile = 1.61 kilometers

The typical pattern of the relationship between accident rate and utilization is summarized below for parallel parking in retail areas.

Parking Utilization (Millions)	Number of Locations	Average Acc/MVM	Average ADT
0.0	2	1.6	10800
0.3	6	4.8	16000
0.8	20	11.3	13500
1.4	23	13.3	11500

1 acc/mvm = 0.62 acc/mvk

As utilization increases, the accident rate also increases. Figure 2 illustrates flattening of the curve at higher levels of utilization.

Land Use

In examining the effect of land uses upon the accident rate, 16 comparisons were tested (see Appendix Table D-2). These were chosen out of the 90 or so possible comparisons because of their interpretability. Most of those not examined involved comparisons between non-homogeneous and/or non-similar land uses. Of the comparisons tested, three

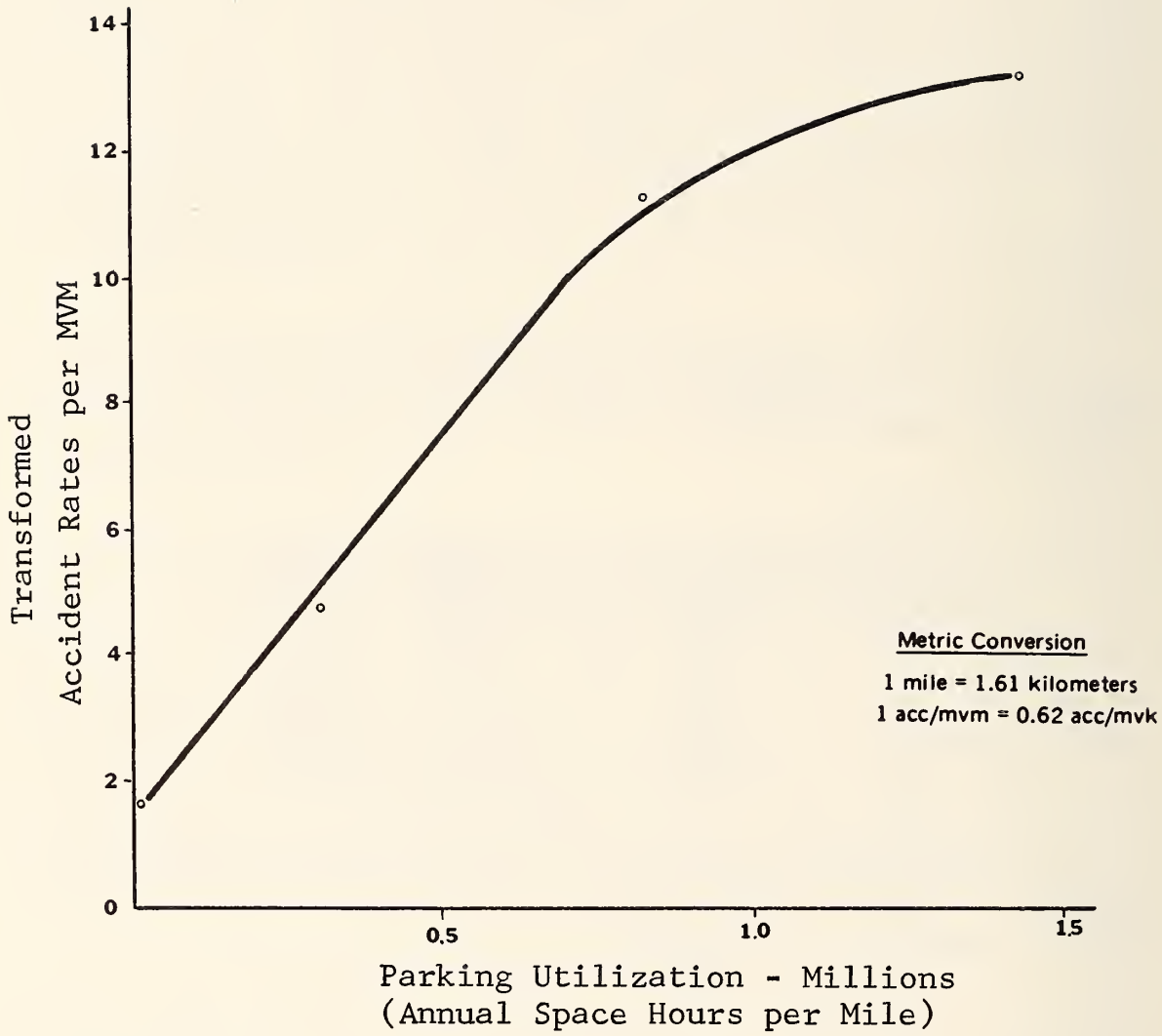


Figure 2. Accident Rates vs Utilization, Parallel Parking in Retail Areas

were significant at the 0.05 level. These are described below.

1. Retail versus Office -- As shown in Table 30, the 60 retail locations had an average accident rate of 11.8/MVM, and the 21 office locations had an average rate of 8.4/MVM. Except for locations with no parking, or with low utilization, the accident rates for retail land use are always higher than for office use. This is expected, considering the higher parking activity associated with retail operations.

2. Retail versus Apartment -- Table 31 shows the 62 retail location comparisons which had an average accident rate of 10.1/MVM, and the 19 apartment streets which had an average rate of 5.4/MVM. The results tend to match expectations; i.e., higher accident rates are associated with higher retail parking activity, except for the top utilization comparison.

3. Miscellaneous versus Apartment -- Table 32 shows the 5 locations with industrial, motel or school/park land uses which were grouped for comparison with 10 apartment land use locations. The average accident rates were respectively 10.7 and 3.7/MVM. The higher activity uses again show higher accident rates.

Table 30. Accident Rates Comparing Retail and Office Land Uses (Major Streets)

Parking Conditions	Parking Utilization (millions)	Number of Locations	Average* Acc/MVM	Average ADT
RETAIL				
No Parking	0.0	17	3.4	25600
Parallel	0.3	6	4.8	16000
Parallel	1.4	23	13.3	11500
Parallel with Skips	1.4	1	41.9	2300
22½° Angle	1.6	9	16.1	4900
45° Angle	2.6	4	12.6	22800
Total/Average		60	11.8	
OFFICE				
No Parking	0.0	4	4.0	15100
Parallel	0.2	2	5.5	7300
Parallel	1.6	7	8.2	6200
Parallel with Skips	1.6	1	18.1	4000
22½° Angle	1.3	5	15.1	3300
45° Angle	1.9	2	6.8	13500
Total/Average		21	8.4	

*The average accident rates reported here and in the following sections are transformed values of the weighted average of the Y or Z values for each configuration involved. They can be obtained from this table (or similar tables) by the following process:

1) add 1.0 to each average acc/MVM value in the Table and take the natural logarithm of this number; 2) multiply each by the appropriate number of locations, and sum; 3) divide the sum by the number of locations; 4) raise the Naperian logarithm e (2.72) to the power given by (3); and 5) subtract 1.0.

See Appendix D for a complete description of the Y and Z transformations.

Metric Conversion

1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

Table 31. Accident Rates Comparing Retail and Apartment Land Uses (Major Streets)

Parking Condition	Parking Utilization (millions)	Number of Locations	Average* Acc/MVM	Average ADT
RETAIL				
No Parking	0.0	17	3.4	25600
Parallel one side	0.9	2	18.9	23000
Parallel	0.8	20	11.3	13500
Parallel	1.4	23	13.3	11500
Total/Average		62	10.1	
APARTMENT				
No Parking	0.0	4	0.7	23500
Parallel one side	0.7	7	8.0	11100
Parallel	0.8	4	5.1	13100
Parallel	1.4	4	17.8	8500
Total/Average		19	5.4	

*See Table 30 footnote.

Metric Conversion

1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

Table 32. Accident Rates Comparing Industrial/ School/Motel/Park vs Apartment Land Uses (Major Streets)

Land Use	Parking Conditions	Parking Utilization (millions)	Locations	Acc/ MVM*	Average ADT
School/Park/ Motel	No Parking	0.0	3	4.3	13100
Industrial	Parallel	0.6	1	15.1	16000
Motel	45° Angle	2.4	1	17.9	9400
	Total/Average		5	10.7	
Apartment	No Parking	0.0	4	0.7	23500
Apartment	Parallel	0.8	4	5.1	13100
Apartment	45° Angle	2.3	2	7.0	13500
	Total/Average		10	3.7	

*See Table 30 footnote.

Metric Conversion

1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

Parking Arrangements

In examining the effect of parking type upon the accident rate, some contrasts were feasible. However, these effectively made only 14 basic comparisons, which are listed in Appendix Table D-5. Three of these had differences in accident rates which were significant at the 0.025 level. These are described below, however in all cases there is an inconsistency in ADT, which will be discussed later.

1. No Parking versus Parallel Parking with Skips -- Table 33 lists data from 17 locations with No Parking, compared with two streets having parallel parking and neutral zones, while holding land use and utilization level constant. (Note that this utilization level of 40,000 annual space hours

per mile for the parallel parking locations was very low relative to other locations). The streets with no parking had an accident rate of 3.4/MVM, while the ones with parallel parking and neutral zones had an average rate of 14.3/MVM.

2. Parallel Parking versus 22½° Angle Parking -- Table 34 shows the groupings used in this comparison, which involved 38 locations with parallel parking and 28 streets with 22½° angle parking. The locations with parallel parking had an accident rate of 10.7/MVM versus 17.2/MVM for streets with 22½° angle parking.

3. 22½° Angle Parking versus 30° Angle Parking -- Table 35 shows the results of comparing these parking types while holding land use and utilization levels constant. There were 22 locations with 22½° angle parking and 5 streets with 30° angle parking. The locations with 22½° angle parking had an average accident rate of 18.9/MVM versus 3.3/MVM for the 30° angle parking. This finding is very surprising.

Table 33. Accident Rates Comparing Parallel with Skips and No Parking (Major Streets)

Parking	Land Use	Parking Utilization (millions)	Locations	Acc/MVM*	ADT
Parallel with Skips	Retail	0.04	2	14.3	5000
No Parking	Retail	0.0	17	3.4	25600

*See Table 30 footnote.

Metric Conversion
1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

Table 34. Accident Rates Comparing 22½° Angle Parking with Parallel Parking (Major Streets)

Land Use	Parking Utilization (millions)	Number of Locations	Average Acc/MVM(1)	Average ADT
22½° ANGLE				
Retail	1.6	9	16.1	4900
Retail/Office	1.6	7	24.3	5000
Office*	0.7	3	11.8	3300
Office	1.3	5	15.1	3300
Office(2)	0.3	2	31.5	2700
Office* (2)	0.5	1	20.0	3000
Office/Misc.	1.2	1	3.8	3200
Total/Average		28	17.2	
PARALLEL				
Retail	1.4	23	13.3	11500
Retail/Office	1.4	3	11.1	6300
Office**	0.6	1	2.6	7000
Office	1.6	7	8.2	6200
Office	0.2	2	5.5	7300
Office/Misc.	1.3	2	6.9	7300
Total/Average		38	10.7	

(1)See Table 30 footnote.

*Each of these configurations were compared to the configuration marked with a double asterisk.

(2)Had parallel on one side.

Metric Conversion

1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

Table 35. Accident Rates Comparing 22½° Angle Parking with 30° Angle Parking (Major Streets)

Land Use	Parking Utilization (millions)	Number of Locations	Average Acc/MVM(1)	Average ADT
22½° ANGLE				
Retail	1.6	9	16.1	4900
Retail/Office	1.6	7	24.3	5000
Office*	0.7	3	11.8	3300
Office(2)	0.3	2	31.5	2700
Office* (2)	0.5	1	20.1	3000
Total/Average		22	18.9	
30° ANGLE				
Retail	1.7	1	7.4	15000
Retail/Office	1.2	2	6.5	15000
Office**	1.0	1	0.0	12000
Office	0.2	1	2.2	11000
Total/Average		5	3.3	

(1)See Table 30 footnote.

*Each of these configurations were compared to the configuration marked with a double asterisk.

(2)Had parallel on one side.

Metric Conversion

1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

One hindrance to a straightforward interpretation of these results is apparent upon close inspection of Tables 33, 34 and 35. In each case, the parking type with the higher accident rates has ADT values of 5,000 or below. Thus, these differences in parking types are confounded with differences in ADT levels.

To more fully appreciate the ambiguity caused by the low ADT values, the comparison between parallel and high angle parking may be considered. As shown in Table 36, this comparison involved 51 and 10 locations, with average accident rates of 10.0 acc/MVM and 7.6 acc/MVM respectively. This difference is non-significant, and there are no ADT values below 5,000. Thus, those comparisons which might have been expected to be significant are not, while those comparisons which might have reasonably been expected to be non-significant (such as 22½° versus 30° parking) are found to be significant. Moreover, if a significance level of 0.10 is used, then all of the Bonferroni comparisons for parking type which involved ADT values below 5,000 would have been significant, while all of those that did not involve ADT values below 5,000 would have been non-significant. Thus the simplest explanation of these results for parking type is that this data does not support the concept of any differences due to parking type, but rather that those comparisons which were found to be significant are all attributable to the differences in the ADT values.

The Scheffe' analysis only added one detail to the above results. While the general pattern of increasing accident rates coinciding with increasing utilization levels is again apparent, this relationship does not continue for the higher utilization levels. For utilization above 1.5 million the accident rate is essentially constant. An illustration of this is given in Table 36. The average utilization level for the 51 locations with parallel parking was 1.24 million. The average utilization for the 10 locations with high angle parking was 2.36 million. Yet the average accident rates are very comparable (10 versus 7.6 respectively). Comparing parallel/retail with high angle/retail, etc., this same pattern of double the utilization but comparable accident rates is again seen. Thus, increasing utilization levels coincide with increasing accident rates, up to a point. Beyond that, increasing utilization does not result in increases in the accident rate.

Table 36. Accident Rates Comparing Parallel Parking with High Angle Parking (Major Streets)

Land Use	Parking Utilization (millions)	Number of Locations	Average Acc/MVM(1)	Average ADT
PARALLEL				
Apartment* (2)	0.7	7	8.0	11100
Apartment*	0.8	4	5.1	13100
Retail	1.4	23	13.3	11500
Retail/Office	1.4	3	11.1	6300
Office	1.6	7	8.2	6200
Apartment	1.4	4	17.7	7500
Retail/Misc.	0.7	3	2.3	15600
Total/Average	1.2	51	10.0	
HIGH ANGLE				
Apartment**	0.8	1	5.3	14000
Retail	2.6	4	12.6	22800
Retail/Office	3.9	1	23.3	12000
Office	1.9	2	6.8	13500
Apartment	3.7	1	9.0	13000
Retail/Misc.	0.8	1	0.0	7000
Total/Average	2.4	10	7.6	

(1)See Table 30 footnote.

*Each of these configurations were compared with the configuration marked with a double asterisk.

(2)Had no parking on one side.

Metric Conversion

1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

Accident Rates for Combinations of Land Uses

In the examination of traffic safety and operations, as related to street improvements, the local public agency has only limited control of land use. In most cases, the uses already exist, as does the curb parking demand (a product of inadequate off-street supply). Therefore, it is appropriate to consider what reductions in accident rates might be achieved by a policy of developing additional off-street parking, and removing curb parking, as part of a general street improvement program.

Road improvements most often relate to major streets. Therefore, the accident rates/MVM have been combined by land uses, as a function of curb parking utilization (which is the dominant factor). Figure 3 gives a plot of average accident rates (not transformed) grouped in this fashion. Single-family residential is shown separately from the other uses. This curve rises steeply at low utilizations, but flattens at higher levels.

The plot of accident rates for streets with apartment, commercial and industrial uses, climbs steeply, and levels just above 1.5 million annual space hours utilization.

Figure 4 shows the combinations of all land uses, and probably best represents the potential average accident reduction. Again, these are actual rather than transformed rates. Four intercepts have been noted, corresponding to utilization levels of 0.0, 0.5, 1.0 and 1.5 million. The average effect of prohibiting parking, where existing demand is at these levels, may be directly calculated from the graph. The reduction of accident rate would amount to 19%, 73% and 81%, respectively.

Accident rates are often calculated for a route by including intersection accidents. Since this and other research found about 40% of accidents to be midblock, the overall effect of curb parking prohibition along a street would be a reduction in the total on-street accident rate, of approximately 8% for 0.5 million utilization, 29% for one million, and 32% for 1.5 million.

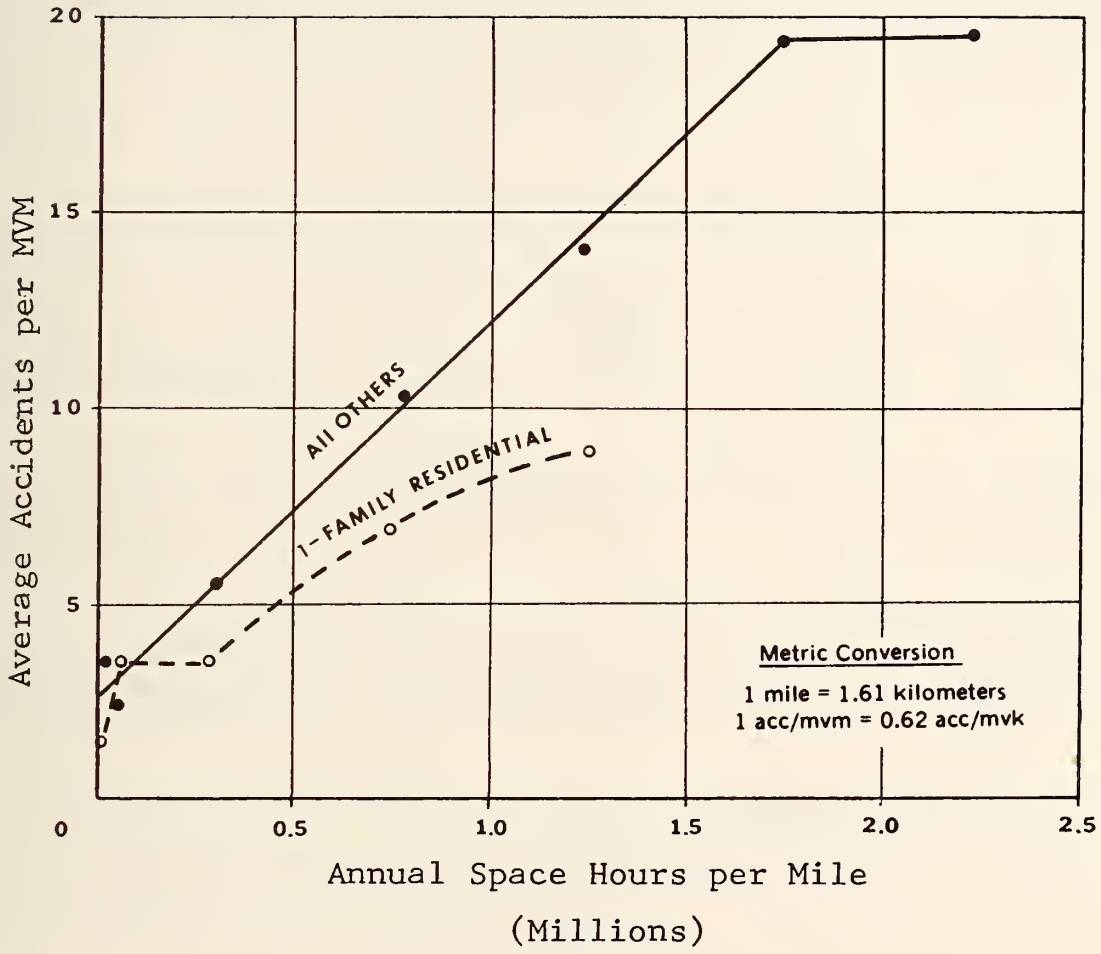


Figure 3. Land Use Combinations, Accident Rates vs Utilization, Major Streets

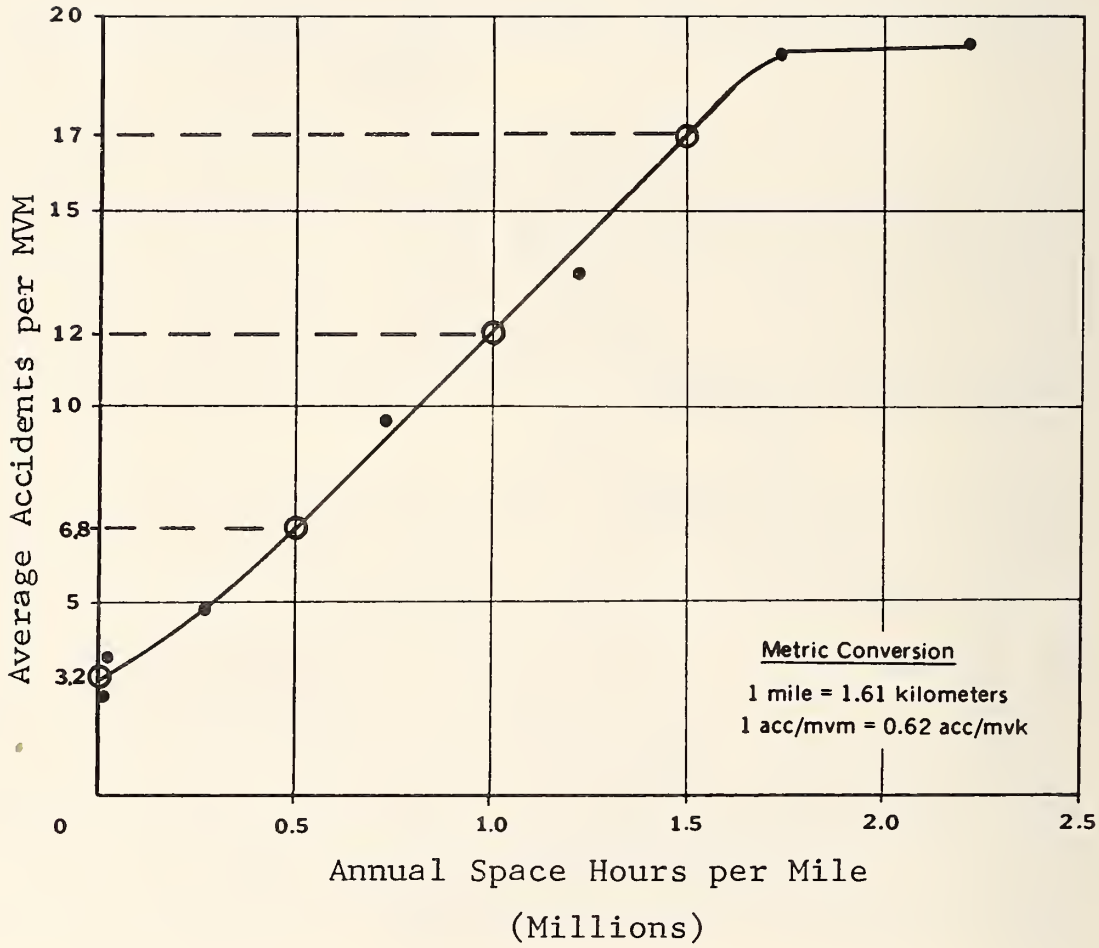


Figure 4. All Land Uses, Accident Rates vs Utilization, Major Streets

Collector Street Analysis

The number of Bonferroni comparisons that could be made for the collector streets was very small due to a limited number of groupings. Appendix Table D-6 lists those comparisons that were made. The only significant difference was found between office and single family residential land use. The one office location had an accident rate of 25.6/MVM, while the 12 residential locations had an average rate of 0.5/MVM. All locations involved had parallel parking and utilizations in the 0.1 to 0.5 million annual space hours per mile range.

The Scheffe' analysis using accident rates divided the 23 different configurations into three groups, with the first and last being significantly different at the 0.05 level. The middle group was indistinguishable from either the first or the last group. Table 37 lists the configurations in order of increasing accident rate, and identifies the groups.

Group I contained 25 study locations in 5 different configurations with average accident rates from 0.0 acc/MVM to 1.5 acc/MVM.

Group II contained 5 study locations in 4 different configurations, with accident rates from 4.8/MVM to 8.0/MVM. These configurations were indistinguishable from those in Groups I or III.

Group III contained 20 study locations in 14 different configurations, with accident rates from 12.7/MVM to 101.5/MVM. Eighteen of these locations had utilizations above 500,000 annual space hours per mile.

Thus, based on the Scheffe' analysis, it can be seen that collector streets with single family residential land use and low utilization levels of on-street parking are significantly safer than those with moderate or high utilizations and non-single family residential land uses.

Table 37. Configurations Ranked by Acc/MVM
(Collector Streets)

Parking	Land Use	Parking Utilization (millions)	No. of Locations	Avg. Acc/MVM*	Avg. ADT
GROUP I					
Parallel	School/Park	0.0	1	0.0	3000
Parallel	School & Single Family Residential	0.18	2	0.0	3100
Parallel	Single Family Resid.	0.21	12	0.5	3025
No Parking	Retail & Apartment	0.00	1	1.3	4300
Parallel	Single Family Resid.	0.04	9	1.5	2050
GROUP II					
Parallel	Single Family Resid. & Apartment	0.22	1	4.8	1500
Parallel	Retail and Office	0.22	1	6.3	2700
Parallel	Apartment	0.89	2	8.0	2800
22½° Angle	Office	0.04	1	8.0	1500
GROUP III					
Parallel	Office and Motel	0.49	1	12.7	2000
Parallel	Retail & Apartment	1.14	1	15.0	1200
Parallel	Motel	0.65	1	18.8	2700
Parallel	Apartment	1.41	3	19.7	1170
Parallel with Skips	Motel	0.59	1	24.1	2000
Parallel	Office	0.28	1	25.5	3100
Parallel	Office	1.15	1	30.0	1500
Parallel	Office & Industry	1.41	1	38.0	1900
High Angle	Apartment	2.22	5	41.1	1840
High Angle	Retail & Apartment	1.86	1	47.6	1600
Parallel & High Angle	Office and School	0.99	1	72.1	1000
Parallel One Side	Office	0.89	1	84.6	800
Parallel	Office	0.94	1	89.0	600
High Angle	Industry	2.57	1	101.5	700

*See Table 30 footnote.

Metric Conversion

1 mile = 1.61 kilometers
1 acc/mvm = 0.62 acc/mvk

Furthermore, for non-single-family residential land uses, accident rates were somewhat inversely proportional to the ADT. Single-family residential data did not show this same dependence upon ADT, however.

Local Street Analysis

Due to lack of ADT data, the response variable in the local street analyses was initially taken to be accidents per mile per year. Again, to meet the assumptions of the ANOVA technique, a transformation was required. The transformation used was $Z = \ln(Acc/MY + 1)$. Utilizing Z, selected comparisons were examined by the Bonferroni technique, and then a Scheffe' post hoc analysis was carried out to look for overall patterns.

Parking Utilization

Out of the six possible comparisons between utilization levels, five were significant at the 0.05 level or better. (See Table 38). Once again, as the number of annual space hours per mile increased, the accident rate (in accidents per mile per year) increased, as shown in Table 39.

Table 38. Comparisons by Utilization Levels (Local Streets)

Comparison	Number of Locations	Significant	Alpha Level
0.0 to 0.1 vs 0.1 to 0.5	96 vs 211	no	
0.0 to 0.1 vs 0.5 to 1.0	96 vs 66	yes	0.01
0.0 to 0.1 vs 1.0 up	96 vs 29	yes	0.025
0.1 to 0.5 vs 0.5 to 1.0	211 vs 66	yes	0.01
0.1 to 0.5 vs 1.0 up	217 vs 75	yes	0.05
0.5 to 1.0 vs 1.0 up	81 vs 75	yes	0.01

Table 39. Accidents per Mile per Year with Varying Parking Utilization Levels (Local Streets)

Parking Utilization (in millions)	Number of Locations	Average* Acc./Mi./Year
< 0.1	96	0.6
0.1-0.5	217	0.9
0.5-1.0	81	2.1
>1.0	75	4.0

1 mile = 1.61 kilometers

*Computed in similar fashion to Table 30 footnote.

Land Use

The ten comparisons for land use are listed in Appendix Table D-7. The three comparisons which were significant show single family residential land use to be safer than retail, apartment, or single family and apartment land uses, as described below:

1. Retail versus Single Family -- Three locations with retail land use were matched against 306 locations with single family land use. The retail locations showed an average of 5.7 acc/MY, while the single family locations showed an average of 1.1 acc/MY. The groups involved are the first three and the last three given in Table 40.

2. Single Family versus Single Family and Apartment -- The 306 single family locations had an average of 1.1 acc/MY, while the 17 locations with a mixture of single family and apartment land uses had an average of 3.7 acc/MY. The three mixed groups used in this comparison are shown in Table 40.

3. Single Family versus Apartment -- The 311 locations with single family residential land use showed an average of 1.1 acc/MY versus 4.7 for 54 apartment land use locations. The ten groups used in this comparison are listed in Table 41.

Table 40. Accidents per Mile per Year for Selected Groups with Varying Utilization and Land Uses (Local Streets with Parallel Parking)

Parking Utilization (in millions)	Land Use	Number of Locations	Average(1) Acc/MY
0.3	Retail	1	0
0.6	Retail	1	13.2
1.6	Retail	1	21.0
0.2	Apt./S.F.R.*	3	1.6
0.7	Apt./S.F.R.*	6	7.3
1.4	Apt./S.F.R.*	8	2.7
0.3	S.F.R.*	211	0.9
0.7	S.F.R.*	66	1.6
1.3	S.F.R.*	29	2.5

1 mile = 1.61 kilometers

(1) Computed in similar fashion to Table 30 footnote.

*Single-Family Residential.

Table 41. Parallel Configurations Comparing Single-Family Residential versus Apartment Land Uses (Local Streets)

Land Use	Parking Utilization (millions)	Number of Locations	Average[1] Acc/MY
Single Family	0.3	211	0.9
Single Family	0.7	66	1.6
Single Family	1.3	29	2.5
Single Family*	0.8	4	1.5
Single Family*	1.1	1	0.0
Total/Average		311	1.1
Apartment	0.4	3	1.5
Apartment	0.8	9	2.1
Apartment	1.5	38	6.3
Apartment*	0.9	3	5.2
Apartment*	1.1	1	16.3
Total/Average		54	4.7

[1]Computed in similar fashion to Table 30 footnote.

*One side only.

1 mile = 1.61 kilometers

Parking Types

The three local street comparisons made for parking type are listed in Appendix Table D-8. None was found to be significant.

The local street configurations were then ranked according to their accident rates/MY, and compared by means of a Scheffe' post hoc procedure. They could be divided into two groups which were found to be significantly different at the 0.05 level. The safer group includes all single-family residential land uses, as well as one mixed single-family residential apartment and some apartment land uses. These latter categories typically had utilization levels below 500,000 annual space hours per mile. The more dangerous group included retail, office, and apartment land uses with utilizations that are almost all above 500,000 annual space

hours per mile. Table 42 shows the general pattern of variation of the accident rate with the changes in utilization with four different land uses. These uses were chosen to represent the spectrum of land uses using a minimum number of categories.

Table 42. Accidents per Mile per Year for Selected Parallel Parking Configurations with Varying Utilization and Varying Land Uses (Local Streets)

Land Use	Parking Utilization (millions)	Number of Locations	Average[1] Acc/MY
Retail	0.3	1	0
Retail	0.6	1	13.2
Retail	1.6	1	21.0
Apartment	0.4	3	1.5
Apartment	0.8	9	2.1
Apartment	1.5	38	6.3
Apt./S.F.R.*	0.2	3	1.6
Apt./S.F.R.*	0.8	6	7.3
Apt./S.F.R.*	1.4	8	2.7
S.F.R.*	0.3	211	0.9
S.F.R.*	0.7	66	1.6
S.F.R.*	1.3	29	2.5

[1]Computed in similar fashion to Table 30 footnote.

*Single-Family Residential.

1 mile = 1.61 kilometers

General Results of Analysis

The results suggest the following:

1. Parking utilization level is a significant factor for all street categories;

    a. No parking is clearly the safest

    b. For up to approximately 1.5 million annual space hours per mile, increases in utilization result in increases in accident rate

    c. For utilization beyond that, the accident rate was not found to increase

    d. The prohibition of curb parking along major streets, where the existing utilization is about one-half million annual space hours per mile, could be expected to reduce midblock accident rates by up to 19%

    e. Prohibitions on major streets with utilization of about one million annual space hours per mile or more could be expected to reduce midblock accidents rates by up to 75%

    f. Because midblock accidents were found to typically represent 40% of total (intersection plus midblock) collisions, the overall accident rate reduction could be up to 8% for the one-half million utilization level and up to 30% for the one million annual space hours per mile level.

2. For all streets, an increasing accident rate was generally associated with changes;

    a. From single-family residential to apartment land use

    b. From apartment to office land use

c. From office to retail land use

d. Since the above changes suggest increases in parking turnover rates and pedestrian activity, it seems appropriate that increases in these variables would be accompanied by increasing accident rates; i.e., these variables may be considered surrogates for increased turnover.

3. Parking configurations were not found to have any effect upon accident rate when parking utilization, land use and type of street are taken into account. The data suggest that any kind of on-street parking is unsafe. The level of utilization, rather than the parking configuration, appears to be the key to the midblock accident rate.

FIELD STUDIES

Introduction

No comprehensive before-and-after studies were conducted during the accident investigation phase of this project. It was recognized that such studies would require an extensive time period for adequate evaluation. This is due to the time necessary to develop proper "after" data.

This decision has proven to be good. The Parking Literature Review revealed several articles which reported before-and-after accident studies of changes in curb parking practices. Most of these involved the conversion of angle parking to parallel parking.

The number of adequate sites across the United States where substantial parking changes are to be made (over several city blocks, for example) during a given year has been found to be very low. Similar sites were sought for before-and-after operational studies as a part of this research, with limited results. Only one really acceptable site was located in spite of much effort. It would appear, then, that extensive coordinated and comprehensive before-and-after accident studies of sites with widespread changes in parking configurations would necessarily involve a lengthy and much more expensive research project.

Even though before-and-after studies were not completed, some operational data were collected. The purpose of these field studies was to quantify certain characteristics of through vehicles and parking/unparking vehicles, as related to various parking configurations. Data collected included:

1. Through vehicle speeds
2. Parking and unparking times
    a. Time in traffic stream
    b. Total maneuver time
3. Through vehicle delays

4. Lateral placement of through vehicles

5. Vehicle-vehicle and vehicle-pedestrian conflicts

6 Sight distance problems

   a. Through driver

   b. Unparking driver

Items one through five utilized time-lapse photography of actual traffic flow, while item six was accomplished in a controlled experiment.

Site Selection

Data for this phase were proposed from at least four different geographic locations, with six sites desired at two of these locations.

Initial inquiries regarding possible or proposed curb parking changes were made at several Institute of Transportation (ITE) meetings. Typically, it was then found that changes had been made "last year", or that perhaps in a year or two some changes "might be made". In short, very few leads developed where significant changes in parking configuration were to be implemented within a time-frame which would accommodate the data collection phase of this study. The one major exception was in Portsmouth, Virginia, where parallel parking was to be converted to 45° angle parking on a two-block section of a major street in the CBD. Two minor sites with proposed changes were also identified in Durham, North Carolina.

In addition to the above study sites, other cities with parking configurations of interest were selected. Two Texas cities (Abilene and Wichita Falls) were selected because of their extensive use of 22½° angle parking. Wichita Falls also had sites with parallel parking with both 8 foot (2.4 m) and 18 foot (5.5 m) neutral zones between parking stalls. The latter was considered similar

to the Travers Tandem layouts, which use a 16 foot (4.9 m) neutral zone.

After selection of a study site in a given city, officials in surrounding cities were contacted. This was to allow data collection at several sites on one trip, where possible. For example, all cities in the vicinity of Portsmouth were contacted, with the cities of Virginia Beach and Hampton, Virginia yielding potential data sites.

Several state highway departments also were asked to inquire about possible major parking changes, but no potential study sites were identified through these contacts.

Field inspection of the sites tentatively considered for study caused several to be eliminated. In two cases, the changes were too minor to be considered, another (which was reported to be on-street angle parking) proved to be random parking off the pavement, while still another had extremely low traffic activity, measured both by parking/unparking vehicles and by volume.

After finding only a very small number of study sites to be available, attempts were made to obtain comparable data in another manner. The cities of Salt Lake City and San Francisco have certain streets where the parking configuration changes from one block to the next, while the land use, traffic volumes and street widths remain basically constant.

Unfortunately, the limited total number of sites identified was further reduced when two planned changes in one city were negated by that city's council. Since "before" data was collected on three sites in that city, three potential before-and-after study sites were lost.

A tabulation of all field study sites is given in Table 43. Details of the filming procedure, study site preparation, film reduction, data recording and codes are given in Appendix E.

Table 43 . Field Study Sites

City	Street Name	Classification	Lanes	Flow	Type Parking, by Sides
Knoxville, Tn.	Main	M*	3	1-W	45° left
	Clinch	C*	1	1-W	Unmarked parallel left
	Sutherland	C	2	2-W	22½° angle,one
Durham, N.C.	Fulton	C	2	2-W(B)	Marked 45° one Unmarked parallel one
	Fulton	C	2	2-W(A)	Marked 45° one No Parking other
	Elf	L	2	2-W	Unmarked parallel both
	9th	M	2	2-W	Marked parallel both
Portsmouth, Va.	High**	M*	4	2-W(B)	Marked parallel both
	High**	M*	2	2-W(A)	45° angle both
Virginia Beach, Va.	8th	L	2	2-W(B)	Unmarked 90° both
	9th	C	4	2-W(B)	Marked 45° one Unmarked parallel one
	18th	L	2	2-W(B)	Marked 45° one Marked parallel one
Wichita Falls, Tx.	Lamar	C*	3	2-W	Parallel both (with 8' neutral zones)
	10th	C*	3	1-W	Parallel both (with 18' neutral zones)
	Scott	M*	4	2-W	Parallel both (with 18' neutral zones)
	Indiana	C*	4	2-W	22½° both
Abilene, Tx.	Cypress	C*	3	1-W	22½° both
	No. 2nd	C*	3	1-W	22½° both
	Walnut	C*	4	2-W	22½° both
	Pine	C*	4	2-W	22½° both
Salt Lake City, Utah	S.Temple	M*	4	2-W	Marked parallel both
	S.Temple	M*	4	2-W	No Parking both
	Social Hall	L	2	2-W	Marked 45° one Marked parallel one

(continued)

Table 43. Field Study Sites (Continued)

City	Street Name	Classification	Lanes	Flow	Type Parking, by Sides
	Chestnut	L	2	2-W	Unmarked 90° one No Parking one
	Chestnut	L	2	2-W	Unmarked parallel both
San Francisco, Ca.	Leavenworth	L	2	2-W	Unmarked 90° one No Parking one
	Leavenworth	L	2	2-W	Unmarked parallel both
	Clement	C	2	2-W	Marked 45° one Marked parallel one
	Clement	C	2	2-W	Marked parallel both

1 foot = 0.3 m.

M = major, C = collector, L = local

W = way, B = before data, A = after data

*Located in CBDs

**Two sites

Data Analysis

The speeds of all through vehicles were calculated using the frame rate, event frame numbers and trap length. The time mean speed and standard deviation were then determined for all undelayed through vehicles. The number, average magnitude and standard deviation of any through vehicle delays were also calculated. (See Appendix E for method of determining vehicle delay). In all these analyses, through traffic was not stratified by lane for multiple lane facilities, or by direction if similar parking configurations existed on both sides of the street.

In addition to the speed of the through traffic stream, the average lateral placement of such vehicles in each lane adjacent to a parking lane (or area) was determined relative to the curb line. Again, the mean and standard deviation were calculated regardless of direction of flow so long as the lane widths and parking configurations on each side of the street were similar. Weighted average placement values for similar parking configurations were then computed, being the distance from curb line to near edge of through vehicle. Table 44 gives summary data (see Appendix E, Tables E-2 and E-3 for individual site data).

Typical lateral placement values were 12.5 feet (3.8 m) for unmarked parallel parking, 13.9 feet (4.2 m) for marked parallel spaces, and 12.4 feet for marked parallel stalls with 18 foot (5.5 m) neutral spaces between stall pairs. At the sites studied, low utilization of unmarked spaces was observed. The more open appearance of this parking and the 18 foot paired parking configuration apparently caused less offset from parked vehicles.

These data show that the width of a parallel parking lane should be 10 to 12 feet (3 to 3.6 m), depending on the through lane width. The narrower (10 foot) through lane needs a 12-foot parking lane, while the wider 12-foot through lane can operate with a 10-foot parking lane.

Table 44. Lateral Placement by Parking Layout and Average Speeds of Through Vehicles

Type Parking	No.	Lateral Place (Ft.)*	Average Speed Through Vehicle (MPH)**
Parallel (unmarked)	244	12.5	17.7
Parallel (varying stalls)	916	13.9	24.3
Parallel (with 8' neutral zone)	286	14.4	21.8
Parallel (with 18' neutral zone)	399	12.4	22.8
Total Parallel	1845	13.4	22.8
22½° Angle	362	16.9	18.4
40° - 45° Angle	564	20.7	19.6
60° Angle	72	22.0	20.4
90° Angle	78	20.8	19.2
Total Angle	1076	20.1	19.1

*1 foot = 0.3 m.

**1 MPH = 1.6 KPH.

For a typical "average" through lane of 11 feet (3.3 m), an equal width parking lane is needed. This also is good practice considering potential use of the curb lane for through traffic.

The 22½° angle parking caused an average lateral placement of 16.9 feet (5.2 m) from the curb line and 45° angle parking caused a 20.7 foot (6.3 m) displacement. It is also interesting to note that 60° parking caused a greater displacement than 90° angle parking, or 22.0 feet (6.7 m) versus 20.8 feet (6.3 m).

These data show that the parking area width adjacent to 10 or 11 foot (3 or 3.3 m) through lanes should be 15 feet (4.5 m) for 22½°, 19 feet (5.8 m) for 45°, and 20 feet (6.1 m) for 60° and over (a reduction for the 90° anomaly should not be considered). With 12 foot (3.6 m) through lanes, these parking area widths may be reduced by 1 foot (0.3 m).

Complete undelayed through vehicle speeds also are presented in Table 44. Speeds averaged 3.7 MPH (5.9 KPH) less when next to angle parking --a difference of nearly 20%.

Average parking or unparking times were determined for all vehicles which parked and/or unparked within the study area covered by each film. These were developed in two parts --the actual time the parking/unparking vehicle maneuvered while occupying a portion of the through traffic lane, and the time spent in maneuvering outside the through traffic lane (or within the parking lane). For reporting purposes, the parking time in traffic and the total parking time have been utilized. Standard deviations of these times were also determined, but in most cases the sample size was too small to be really meaningful.

Parking times for parallel parkers were stratified by the type of maneuver used to park. If a rather long curb space is available, a frequent maneuver is to pull into the curb directly. A back-in maneuver is required, however, if the available parking space is limited. The back-in maneuver required more time in the traffic stream in all cases except one. This location had 20 foot (6.1 m) stalls and an 18-foot (5.5 m) neutral space between stall pairs. Although

the sample size was very small (N = 4 in each case), it appears that the head-in parkers did not completely clear the traffic stream on the initial pull-in, requiring 10.0 seconds for clearance against 3.4 seconds for the back-in maneuver. Total maneuver times reflected the addional back-and-forth positioning required, with total parking times averaging 26.5 seconds for head-in and 17.4 seconds for back-in maneuvers.

Tables 45 and 46 show parking/unparking times by study site. Weighted averages are shown for all similar maneuvers for similar parking configurations. The total parking plus unparking time for parallel layout is 24.2 seconds by head-in versus 20.9 seconds for similar angle parking maneuvers. However, if the parallel parking is by back-in, the total of this plus unparking time is 28.1 seconds, or over one-third longer than for angle parking entry and exit.

Delay and type of conflicts, by type of parking layout, are given in Appendix Table E-4.

Vehicle Classifications

A frequent comment relative to any on-street angle parking is the sight distance restriction during the unparking maneuver. Measurements were made for standard size automobiles and are reported later. One common concern, however, is the sight distance when there is a vehicle mix --for example, a pickup truck with camper or a van parked immediately upstream of the unparking vehicle.

Two types of analyses were made in order to determine the potential magnitude of this problem, both as to the increased accident potential and unparking times. Vehicle classification counts were conducted in Wichita Falls, Texas for the following vehicle types: standard size cars, compact cars, station wagons, pickup trucks, pickup trucks with campers, vans and large trucks. These classification studies were performed in three distinct areas: on retail streets, in shopping center parking lots and along residential streets.

Table 45. Parallel Parking and Unparking Times (in seconds)

Type Parking	Location	Head-in Parking Time			Back-in Parking Time			Unparking Time		
		No.	In Traffic	Total	No.	In Traffic	Total	No.	In Traffic	Total
Parallel (unmarked)	Clinch	4	4.5	17.6	1	8.0	8.0	6	3.6	11.4
	Leavenworth				1	7.0	19.6			
	Fulton	1	3.9	19.1						
Subtotal (Avg.)		5	4.4	17.9	2	7.5	13.8	6	3.6	11.4
Parallel (varying stall lengths)	9th	16	2.3	5.9				17	1.6	8.9
	Clement				1	8.1	26.9	1	16.0	17.5
	S. Temple				1	5.7	8.0			
	18th	2	4.2	16.6				2	2.3	17.1
	Social Hall	5	3.5	8.4				11	3.1	5.5
Subtotal (Avg.)		23	2.7	7.4	2	6.9	17.5	31	2.6	8.5
Parallel (w/8' neutral zones)	High	7	4.0	14.0	3	12.4	18.9	12	4.8	9.5
	Lamar	44	3.7	13.9	19	14.2	22.8	64	4.5	10.5
Subtotal (Avg.)		51	3.7	13.9	22	14.0	22.3	76	4.5	10.3
Parallel (w/18' neutral zones)	10th	4	10.0	26.5	4	3.4	17.4	6	5.4	10.3
	Scott	15	6.0	19.0	4	14.4	41.6	20	2.5	6.9
Subtotal (Avg.)		17	6.5	19.9	8	8.9	21.1	26	3.2	7.7
PARALLEL TOTAL (Avg.)		96	4.3	14.7	34	9.3	18.6	139	3.5	9.5

Table 46. Angle Parking and Unparking Times
(in seconds)

Type Parking	Location	Head-in Parking Time			Unparking Time		
		No.	In Traffic	Total	No.	In Traffic	Total
22½° Angle	Indiana	29	2.8	5.5	23	6.7	10.3
	Cypress	27	3.4	5.2	28	5.6	8.4
	No. 2nd	4	2.1	4.2	2	3.9	7.6
	Pine St.	91	3.8	6.2	101	6.0	8.7
Subtotal (Avg.)		151	3.5	5.8	154	6.0	8.9
40° - 45° Angle	Main	9	1.4	3.5	11	3.9	8.3
	Main	12	1.8	4.6	13	2.6	8.9
	High	40	6.3	10.9	40	6.9	11.6
	Clement	5	6.6	10.2	5	6.4	11.3
	9th	1	3.8	8.9	1	2.0	4.6
	18th	2	4.2	16.6	2	2.3	17.1
Subtotal (Avg.)		69	4.8	8.9	72	5.4	10.6
60° Angle	Fulton	1	3.1	4.9	1	13.1	21.3
Subtotal (Avg.)		1	3.1	4.9	1	13.1	21.3
90° Angle	8th	6	7.6	11.4	7	14.5	17.6
	Leavenworth	9	7.6	9.8	6	4.2	7.5
Subtotal (Avg.)		15	7.6	10.4	13	9.7	12.9
ANGLE TOTAL (Avg.)		236	4.8	7.5	240	8.5	13.4

Figure 5 presents the results of the classification checks by area. Each type is shown as a percentage of the total in each area. Some interesting data were obtained. A large percentage of pick-up trucks is found in the residential area (21%), but only 5% were observed parked in the retail area and 6% in the shopping center lots. Pick-ups with attached campers were also few, with 2% found in the retail area, 1% at shopping centers, and none counted in the residential on-street parking. One explanation for this low number of trucks outside the residential area is that those who are doing the shopping do not utilize the family pick-up in that shopping trip.

An equal percentage of vans, or 3%, was noted in retail and residential areas, with 1% found in the shopping center count. While these small values might be misleading, the data might suggest that vans are used for shopping trips more regularly than are pick-up trucks.

Assuming that a station wagon presents less of a sight distance problem than do pick-ups with campers, van and large trucks, the latter three classes of vehicles can be grouped to indicate the expected number of sight limiting vehicles to be expected in the Wichita Falls CBD. A total of ten such vehicles out of the 158 were noted, or 6%. Including pick-ups without campers gives a total of 18, or 11%.

In the Wichita Falls and Abilene CBD areas, a total of 154 unparking vehicles were observed on the time-lapse films, with 8 of these (5%) recorded as having an upstream sight distance restriction caused by a pick-up with camper, van or truck. Adding in 11 observed upstream pick-ups without campers gives a potential restriction to 19 vehicles out of the 154, or 12%. These values confirm the relative magnitude of the situation in that area.

Comparative Analyses

Although only one acceptable before-and-after study site was found where substantial parking changes were made during the study period, five additional comparative studies were made. In each of these, two adjacent or nearby blocks

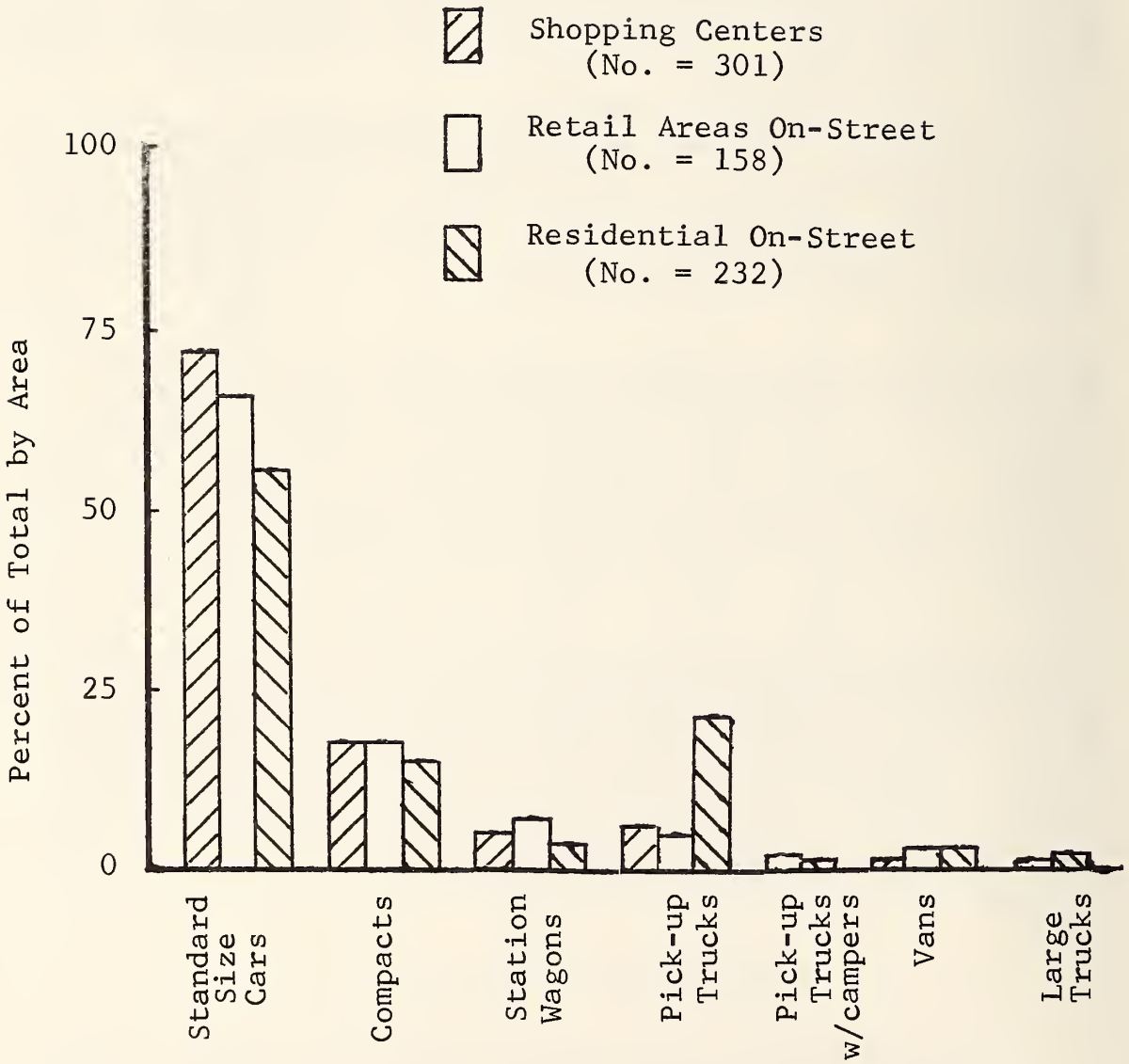


Figure 5. Vehicle Classification by Area
Wichita Falls, Texas

of the same street were selected which had different parking layouts. Care was taken to assure similar land uses, traffic flows and traffic compositions. In two cases (Chestnut Street and Leavenworth Street) grades were appreciably different, with steeper grades in the blocks having 90° angle parking.

While the data are not sufficient to draw statistically valid conclusions relative to parking practices across the nation, several interesting results did arise from the six comparisons (one before-and-after, five comparative studies). Perhaps the best data were obtained on High Street, where two blocks of a 59 foot (18 m) street with four through lanes and parallel parking on both sides were converted to carry two through lanes plus 45° angle parking on both sides. Through traffic speeds dropped from 24.5 MPH (39 KPH) to 15.6 MPH (25 KPH), or 36%. The percentage of delayed vehicles increased from 5 to 30, while the average delay more than doubled (4.8 seconds to 9.8 seconds). Parking times were decreased substantially, while unparking times (both total and time in the traffic stream) were slightly increased. These results, as well as similar results for the other comparative sites, are shown in Tables 47 and 48.

Through traffic speeds on Clement Street were substantially lower, 16.0 versus 22.4 MPH (26 versus 36 KPH) where angle parking was utilized on only one side.

The Chestnut Street and Leavenworth Street data show relatively little difference in through traffic speeds as the parking configuration changes. However, sample sizes are comparatively small, and it should be noted that these were local streets in residential/apartment areas having low pedestrian activity.

South Temple Street was a 4-lane major route carrying approximately 24,000 vehicles per day. Parking turnover and pedestrian activity were low. Through traffic speeds were fairly consistent in areas with and without parallel parking. It appeared that the presence of parked cars did not have any effect on the motorist's perception of a safe speed on this facility.

Table 47. Comparative Lateral Placements and Speed

Location	Parking Layout Each Side	Street Width (ft)*	Adjacent Lane Width (ft)*	Lateral Placement No.	Lateral Placement Feet*	Through Vehicles No.	Through Vehicles Speed (MPH)**
Clement	Parallel/45° Angle	54.0	21.7/31.8	165	14.0/16.4	93	16.0
Clement	Parallel both sides		27.0	181	16.2	170	22.4
Chestnut	90°/No Parking	38.5	28.5/-	9	23.3/-	31	18.9
Chestnut	Parallel both sides			36	12.9	32	21.1
Leavenworth	90°/No Parking	38.6	27.8	49	19.4	82	19.3
Leavenworth	Parallel both sides		19.3	61	12.8	59	18.4
Fulton	60°Angle/Parallel	44.0	***	72	21.4/12.8	70	18.9
Fulton	60° Angle		30.3	47	22.3	84	21.8
S. Temple	Parallel both sides	60.0	20.0	179	13.2	295	30.9
S. Temple	No Parking (w/turn lane)		14.0			249	30.2
High	Parallel (w/8' space)	59	19.0	71	11.2	165	24.5
High	45° Angle		29.6	383	21.4	239	15.6

*1 foot = 0.3 meters.

**1 MPH = 1.6 KPH.

***No lane marking.

Table 48. Comparative Parking, Unparking and Delay Times (in seconds)

Location	Parking Layout Each Side	Head-in Parking Time			Unparking Times			Delays			Proportion Delays
		No.	In Traf.	Total	No.	In Traf.	Total	No. Und.	No. Delay	Avg. Delay	
Clement	Parallel/45° Angle	5	6.6	10.2	5	6.4	11.3	93	23	7.1	20%
Clement	Parallel both sides				1	16.0	17.5	183	13	4.4	7%
Chestnut	90°/No Parking							31	3	5.1	9%
Chestnut	Parallel both sides							32	4	7.0	11%
Leavenworth	90°/No Parking	9	7.6	9.8	6	4.2	7.5	82	7	7.7	8%
Leavenworth	Parallel both sides							59	0	-	0%
Fulton	60° Angle/Parallel	1	3.9	19.1				70	0	-	0%
Fulton	60° Angle	1	3.1	4.9	1	13.1	21.3	84	5	5.4	6%
S. Temple	Parallel both sides							303	8	9.8	3%
S. Temple	No Parking (w/ turn lane)							249	0	-	0%
High	Parallel (w/8' space)	7	4.0	14.0	12	4.8	9.5	165	9	4.8	5%
High	45° Angle	40	6.3	10.9	40	6.9	11.6	239	104	9.8	30%

1 foot = 0.3 meters

The field studies also identified pedestrian conflicts due to parked car sight restrictions, or parking activity, as shown below:

Parallel, unmarked	0	
Parallel, variable length	0	
Parallel, with 8' neutral zone	0	
Parallel, with 18' neutral zone	3	
Subtotal	3	(of 1,845 parkers)
22½° angle	1	
40° - 45° angle	2	
60° angle	0	
90° angle	1	
Subtotal	4	(of 1,076 parkers)
TOTAL	7	(of 2,921 parkers)

These data show the pedestrian conflict to average about 1 per 600 for parallel parking and 1 per 250 for angle parking. However, the overall proportion found is so low (one-fourth of 1%) as to be insignificant. This compares with about 1% of total midblock accidents found to involve pedestrian-parked car conflicts (Accident Findings Section).

Controlled Sight Distance Studies

The purpose of this phase of the research was to determine sight distance for specific angles of parking. Three characteristics were studied for 45°, 30°, and 22½° angle parking: (a) upstream sight distances from the driver pre-parking to unpark, to oncoming vehicles, (b) sight distance for the same driver after backing to edge of through lane, and (c) the view by an oncoming driver in the travel lane.

A section of an asphalt parking lot was blocked off and parking stalls for each angle were marked with 4-inch (10 cm) pavement marking tape. Two full-sized 1971 Plymouth vehicles were centered in adjacent stalls; one a Fury I and the second a Fury III. Both cars had a wheelbase of 120 inches (3 m), overall length of approximately 18 feet (5.5 m), and an overall width of about 80 inches (2 m). Loca-

tion of the center of an adjacent 11 foot (3.3 m) traffic lane was marked with chalk and a third car was located 100 feet (30 m) upstream for photographic purposes. The position of a driver with the front seat in a centered position in the parked cars was determined to be 2.1 feet (0.6 m) from the left side of the car and 8.6 feet (2.6 m) from the front of the car.

For sight distance measurements, a target was chosen that would be equivalent to the height of the bottom point of the front left windshield post (A-post) of a car. The target was moved along the centerline of the traffic lane until it could be seen by the driver of the first parked car. The parallel distance along the curb was measured and the actual sight distance from the driver of the parked car to the target was determined. The 45° angle parking stalls were 18 feet (5.5 m) by 8.5 feet (2.6 m).

Figure 6 shows the parked cars as viewed from the approaching vehicle 100 feet (30 m) upstream. The approaching vehicle is not visible to the driver in the downstream parked car, as shown in Figure 7. In fact, the actual sight distance determined from the driver's eye position to the approaching target was only 57 feet (17 m). By backing the parked car to the edge of the traffic lane (18.4 feet or 5.6 m from the curb) the sight distance was increased to 70 feet (22 m).

Table 49 gives these dimensions as well as those for 30° and 22½° parking.

The 30° angle parking stalls were also 18 feet (5.5 m) by 8.5 feet (2.6 m) and were adjusted for a 1 foot (0.3 m) curb overhang. The amount of overlap between parked vehicles (extent to which rear bumper position of downstream vehicle overlaps front bumper position of adjacent vehicle, measured parallel to curb which would block direct passage) was noticeably less than that of the cars parked at 45°. Figure 8 shows the parked cars as viewed from an approaching vehicle 100 feet (30 m) upstream. This vehicle is just barely visible to the driver of the downstream parked vehicle, as shown in Figure 9.

Figure 6. 45° Parked Cars From 100 Feet (30 m)

Figure 7. Driver's Upstream View From 45° Parked Car

Table 49. The Effect of Parking Angle on Sight Distance and Pedestrian Action

Type Parking	Sight Distance of Unparking Driver*	
	Sight Distance (Vehicle in Slot)	Sight Distance (Vehicle Backed to Edge of Lane)
22½°	91'	137'
30°	72'	147'
45°	57'	70'

*1 foot = 0.3 m

Figure 8. 30° Parked Cars From 100 Feet (30 m)

Figure 9. Driver's Upstream View From 30° Parked Car

The evaluation of parking vehicles at an angle of 22½° is relatively new in the study of on-street parking. The measurements used were taken from "A Study of On-Street Parking Arrangements".(5) Each stall was 18 feet (5.5 m) by 8 feet (2.4 m), with a bumper overhang of 1 foot (0.3 m) over the curb. Unlike the 30° and 45° angle patterns, there is no overlap between cars parked at 22½°.

Figure 10 shows a view of the 22½° parked cars from the through vehicle. An approaching upstream vehicle at 100 feet (30 m) is visible from the driver's seat of the parked car, as shown in Figure 11.

The sight distance determined from the unparking driver's eye position was 90 feet (27 m), an improvement over the sight distances found for 30° and 45° angles. As the parked car is backed to the edge of the travel lane (14.0 feet or 4.3 m from the curb), the sight distance becomes 137 feet (42 m), or 10 feet (3 m) less than the sight distance of the similarly positioned car in the 30° angle parking space. This is due to the smaller stall space and the shorter distance from the curb to the edge of the travel lane.

Pedestrian Studies

The sight distance layouts were also used to evaluate the view and actions of pedestrians. In studying the view of a pedestrian between parked cars as seen by oncoming drivers, several things were noticed. Generally, a pedestrian who is taller than the parked cars can be seen by oncoming drivers for any angle of parking. For the cars used in this study, a pedestrian taller than 57 inches (145 cm) would be visible the full length of the car. However, a slightly shorter pedestrian would only be visible over the trunk lid of the parked car. The height of the trunk of the study cars was 40 inches (100 cm). According to the 1976 Collier's Encyclopedia, most children between the ages of five and twelve years are tall enough to be seen over the trunk, but not over the roof, of the parked vehicles. Children under the age of five years are not tall enough to be seen over a car trunk 40 inches high. These children

Figure 10. $22\frac{1}{2}°$ Parked Cars From 100 Feet (30 m)

Figure 11. Driver's Upstream View From $22\frac{1}{2}°$ Parked Car

would not be visible to oncoming traffic until they had come from behind the parked car immediately adjacent to the travel lane.

With the 22½° angle parking, there was no overlap of the parked cars in this controlled placement test. Therefore, the pedestrian could walk (or run) directly from the curb into the travel lane, as shown in Figure 12, and not be forced to slow down or turn toward traffic when passing between cars.

The 30° angle parking shows some overlap of the parked cars, as seen in Figure 13. The pedestrian cannot take a direct path from curb to street, so would be forced to turn somewhat, thus facing oncoming traffic. Also, a reduction in walking speed is possible due to the required swerving between the cars.

It was observed that the 45° angle parking was not quite as effective as 30° in forcing the pedestrian to turn toward oncoming traffic, due to the larger angle. (See Figure 14). However, 45° angle parking constrained the pedestrian more due to the greater overlap of the parked cars.

According to the Department of Transportation's "A New Look at Pedestrian Safety," published in November 1975, ". . . certain pedestrian actions are always present . . ." in vehicle-pedestrian accidents. According to this booklet, "These behavioral functions can be used to describe any particular pedestrian accident:

" - Search: The focus of the driver's or pedestrian's attention.

- Detection: Actual driver or pedestrian perception of the environment.

- Evaluation: Awareness of a potential accident by either the pedestrian or the driver can lead to action that will prevent it.

- Decision: Determination by either the driver or the pedestrian of what action is needed to avoid an accident.

Figure 12. Pedestrian Passing Between 22½° Parked Cars

Figure 13. Pedestrian Passing Between 30° Parked Cars

Figure 14. Pedestrian Passing Between 45° Parked Cars

- Human Action: The motor behavior of the driver or pedestrian to carry out the decision.

- Vehicle Action: The response of the vehicle to the behavior of the driver.

"When each of these behavioral functions is performed, a potential accident is usually avoided. A failure at any step will usually cancel the remaining steps."

The step that this phase of the study was most concerned with was the first --Search. The limited evaluations made herein suggest that 30° angle parking in fact increases the search potential for the pedestrian, because the travel path between parked cars turns the pedestrian toward the line of traffic, easing the task of focusing attention, or searching. In addition, a moderate reduction in pedestrian walking (or running) speed may be occasioned by the required change in direction for 45° parking. It should be noted, however, that these potential advantages do not hold with the 22½° parking configuration, thus providing a disadvantage which puts that layout in the same category as parallel parking and 90° angle parking.

The relative effects of the different angles of parking upon sight distances and potential pedestrian actions are summarized below, however it must be remembered that no field studies were conducted to verify the entries. These were subjectively determined by the study staff while observing and walking between the parked cars in the controlled field studies:

Type Parking	Effect on Direction	Effect on Walking Speed
22½°	none	none
30°	moderate change	slight decrease
45°	slight change	moderate decrease

Summary

The field studies suggest that speeds of, and delays to, through vehicles are related to parking type. Conflicts were shown to be related, with parking vehicles causing more conflicts when parking parallel, and unparking vehicles causing more conflicts with angle parking layout. Speeds of through vehicles averaged 3.7 MPH (6.0 KPH) less when adjacent to angle parking, as compared with parallel.

Few pedestrian conflicts with curb parking were found during the field studies; amounting to only one-fourth of 1% of parking activity. Parking/unparking vehicle conflicts with through traffic occur approximately seven times as frequently as vehicle-pedestrian conflicts.

Backing sight distance restrictions caused by special vehicles such as campers were found to have no effect on unparking times from angle parking slots. However, no conclusions could be made relative to the accident potential of those restrictions because of lack of information in accident reports.

Sight distance afforded to the backing driver was less for 45° angle parking than for 22½° or 30° angles, while the 22½° angle would probably modify pedestrian actions by a lesser amount than 30° and 45° angles.

The combined width needed for an adjacent lane plus parking lane was determined to be 22 feet (6.6 m) for parallel layout, 26 feet (7.8 m) for 22½°, 30 feet (9.0 m) for 45°, and 31 feet (9.3 m) for 60° and over.

CONCLUSIONS

The research was intended to examine relationships among parking configurations (angle, parallel or no parking), parking density, traffic flow, street width, pedestrian activity and highway safety.

The literature review identified 27 studies of accidents as related to curb parking. The use of angle parking was identified in many studies as significantly more hazardous than parallel. However, the use of angle parking has been endorsed by some researchers as offering potentials for safer pedestrian behavior when crossing between parked vehicles, while one agency has reported 22½° parking to be safer than parallel.

Assuming one side of a typical block of an urban CBD, the following numbers of parking spaces are typical: 13 for parallel or at 22½°; 17 at 30°; or 21 at 45°. Thus, the higher angle layout increases parking capacity by about 60%.

With respect to parking configurations, the variables found in this research to be associated with accident rates include: a) functional classification of street; b) utilization of parking spaces; and c) abutting land use.

Increased parking utilization; i.e., annual space hours per mile, results in significantly higher accident rates, up to approximately 1.5 million. Streets abutting land uses which generate high parking turnovers and pedestrian activity (land use has been used as a surrogate for pedestrian volumes) have higher accident rates when compared with lower intensity uses. Thus, a given utilization of parking along a retail street results in a higher accident rate than if the same utilization were found on a street abutted by single-family residential. Heavily used parallel parking was found to have accident rates comparable to heavily used high angle parking having approximately double the parking utilization. However, angle parking results in poorer operating conditions and allows higher utilization per curb mile than does parallel parking.

The prohibition of curb parking provides the safest condition. Minimizing the use of any curb parking (whatever the layout), such as by providing adequate, convenient off-street parking, will give the next safest operation.

The research data shows that prohibition of curb parking along major streets could reduce midblock accidents by an average of 19% with an existing parking utilization of one-half million annual space hours per mile. For a one million parking utilization level, the prohibition could reduce midblock accidents by 73%. If intersection accidents are included in the rate calculation per million vehicle miles, the overall reduction is then equivalent to 8% and 29%, respectively. No categorical differences among parking layouts could be substantiated by the statistical analysis when street function, land use and utilization level were all comparable.

In this research, the proportion of parking accidents to total accidents within the study areas was 20%, which agrees with other research. Only 2% of intersection accidents were found to be parked-related. Of all property damage-only type accidents, 24% were parking-involved. Of all injury/fatal accidents, 7% were found to be parking-involved. Curb parking can therefore be seen as a pronounced factor in traffic safety.

Considering functional classifications, the midblock accidents that were parking-related accounted for 49% of the collisions along major streets, 68% along collector streets, and 72% along local streets. These data reflect <u>averages</u>, including study sections with parking restrictions (nearly one-third of the major streets had 'no parking' regulations). Thus, some sections of major streets had extremely high percentages of accidents related to curb parking.

On 1-way major streets, 60% of midblock accidents were found to be parking-related compared with 43% for 2-way streets. The largest difference appeared to result from the unparking maneuver; however, no one accident type clearly stood out as the basic cause of the higher 1-way street proportion.

A summary tabulation of midblock accident percentages by type of parking involvement and street classification is given in Table 50.

Table 50. Per Cent of Midblock Accidents by Type of Parking Involvement

Accident Category*	Street Classification			
	Major	Collector	Local	Combined
Open Door				
Veh.-Pk.Car	3	0	1	2
Parking Maneuver				
Veh.-Pk.Car	6	5	2	5
Sight Restriction				
Veh.-P/B	0	0	2	1
Stationary Parked Veh.				
Veh.-Pk.Car	23	50	59	31
Veh.-P/B	0	0	1	0
Unparking Maneuver				
Veh.-Pk.Car	16	13	6	14
TOTAL PARKING RELATED	48	68	71	53

*Veh.-Pk.Car = moving vehicle striking parking-involved vehicle (if 1% or more).

Veh.-P/B = vehicle striking pedestrian or bicycle rider (if 1% or more).

The parking accident involvements, as a percent of total midblock accidents, may be ranked as follows:

1. Stationary parked vehicle 31%
2. Unparking maneuver 14%
3. Parking maneuver 5%
4. Door opening 2%
5. Sight obstruction for pedestrians. 1%

Decisions regarding the effect of parking should consider the relative magnitudes of accident potential.

A correlation between street width and accident rates was not found for any of the three types of streets.

Field studies meansured speeds and delays to through vehicles as well as parking/unparking times and conflicts. Vehicles engaged in parking maneuvers caused more conflicts when parking parallel, while the unparking maneuver created more conflicts with the angle layouts, as found in other studies. Speeds of through vehicles averaged 3.7 MPH (6.0 KPH) less when adjacent to angle parking, as compared with parallel.

A before-and-after study, conducted on High Street in Portsmouth, Virginia, allowed direct measurement of the effects produced by a change from parallel to angle parking. Two blocks of a 59 foot (18 m) street with four through lanes and parallel parking on both sides were converted to carry two through lanes plus 45° angle parking on both sides. Through traffic speeds dropped from 24.5 MPH (39 KPH) to 15.6 MPH (25 KPH), or 36%. The percentage of delayed vehicles increased from 5 to 30, while the average delay more than doubled (4.8 seconds to 9.8 seconds). Parking times were decreased substantially, while unparking times (both total and time in the traffic stream) were slightly increased.

Over 2,900 parking activities were observed. Few mid-block pedestrian conflicts with curb parking were found, amounting to only 0.25% of the parking activity. The parking/unparking vehicle conflicts with through traffic occurred about 7 times as frequently as the vehicle-pedestrian conflict.

Sight distance afforded drivers backing from angle parking stalls was found to be less for 45° parking than for the flatter 22½° or 30° angles. Furthermore, field studies indicated that the 22½° layout would probably modify pedestrian actions by a lesser amount than would the 30° or 45° angles.

The combined width needed for an adjacent lane plus parking lane was determined to be:

Parallel; 22 feet (6.6 m)

22½° angle; 26 feet (7.8 m)

45° angle; 30 feet (9.0 m)

60° and over; 31 feet (9.3 m)

The curb parking attitudes and policies of public agencies, as identified in the literature search, may be summarized as follows:

1. Recognition that high hazard is associated with curb parking in general.
2. Belief that angle parking is especially hazardous.
3. Concern for the congestion affect of curb parking.
4. The taking of positive steps to reduce future curb parking demand, by constructing new off-street facilities, and by enactment and enforcement of zoning controls requiring off-street parking supply for new developments.
5. The extensive use of rush hour and of total parking prohibitions.
6. The refusal to allow new angle parking installations.
7. The elimination of existing angle parking or conversion to parallel type.

This study supports some of the literature findings in that curb parking, where allowed and utilized, does produce increased accident rates. This research, however, does not support items 2, 6 and 7 above, because parking configuration was not found to be a significant factor in accident rate variation, when parking utilization, land use and street type are considered.

In summary, this study indicates that allowance of any type of on-street parking in areas of high demand and activity (such as with retail land use) will result in signifi-

cantly higher hazard than if parking is prohibited. The magnitude of the hazard decreases, however, as parking activity lessens. Thus, streets abutted by apartment or single-family residential land use have successively lower hazard with a given parking utilization.

The study results support previous findings on higher delay, lower operating speed and reduced effective street width for movement of traffic, when relating angle parking with parallel.

Future Research

The findings on parking utilization suggest that future studies of accidents related to parking configuration should include measurement of utilization. Moreover, studies of the effect of a change of parking in one block should include similar studies simultaneously made for nearby blocks. If a parking prohibition, or a reduction of spaces caused by change from angle to parallel, results in a higher utilization in adjacent blocks, accidents on such streets might increase. Thus, the overall impact of a change should be assessed and not just limited to the specific study site.

APPENDIX A --SELECTED ABSTRACTS

1. Box, P. C., "Streets should Not Be Used as Parking Lots," Congressional Record, Vol. 112, No. 187, November 21, 1966, pp. 67-74. (Also in HRB Special Report 93).

   Accidents and traffic congestion caused by curb parking are discussed. About 17% of urban accidents and 4% rural involve parking activity on streets. A four year study of some 1,200 blocks in one city found parked cars caused 12% of all accidents on major streets, 43% on minor streets, and 18% overall. Accident rate per mile was 14 parking accidents per year on major streets and only 1.8 on minor streets. Accident rates were nearly three times greater in dense development (apartment and business areas) as compared to single family residential. Considering only mid-block type accidents, curb parking accounts for about two-thirds of the number.

   Not only stationary parked vehicles were struck, but parking maneuver activity, opening vehicle doors, pedestrians struck while emerging behind parked vehicles, and parked vehicles blocking driver view of intersections and driveways are cited as accident causes.

   Effects of congestion relate not only to the parked car, but also to maneuver activities, and parallel parking can affect up to 17 feet (5.2 m) of street space while angle parking can use up to 40 feet (12 m). Other factors such as pavement widths are discussed.

2. Highway Research Board, "Highway Capacity Manual," Transportation Research Board, Special Report #87, 1965.

   Contains discussion of curb parking effect on capacity.

3. Highway Research Board, "Parking Principles, Special Report No. 125," Transportation Research Board, Washington, D. C., 1971, p. 217.

Contains curb parking layout designs (paired-parking) and discussion of congestion and hazard effects of angle and parallel arrangements.

4. Synder, M. B., "Traffic Engineering for Pedestrian Safety: Some New Data and Solutions," Transportation Research Board Record No. 406, Washington, D. C., 1972, p. 21.

This paper describes involvement patterns for a number of specific types of pedestrian accidents drawn from a study of 2,100 cases. The effect of curb-parked vehicles as a factor in "dart-out" accidents (24% of pedestrian involvements) examined the possibility of using angle parking on local residential streets. This angle parking would perhaps "angle" the pedestrian into traffic, thus directing his attention in that direction, would allow the pedestrian to merely swerve (rather than stop) to avoid being hit, and would offer improved sight distance for the driver who would be further away from the line of parked vehicles. Limited maneuver time data are also reported and research is recommended.

5. Zeigler, C. D., "A Study of On-Street Parking Arrangements," Texas Highway Department, Report No. SS-19.1, August 1971, 44 pages.

Operating characteristics of parallel parking and at an angle of 22½° with the curb were analyzed, using graphical methods and vehicles in parking situations. Parallel parking was considered to provide the potential for considerable interference with traffic, to cause some parking vehicles to encroach upon two travel lanes, and to expose pedestrians entering and leaving parked cars to extreme hazard. The flat angle parking was found to be extremely convenient, to provide safety to pedestrians entering or leaving the vehicle, to provide improved view

to the unparking driver, and to provide a safer unparking maneuver.

6. National Safety Council, "Relation of Parking to Traffic Safety," Transactions, National Safety Council, Vol. 2, 1946, pp. 262-273.

Early data on curb parking accidents found them to be 5% to 28% of total accidents (10 large cities, 1940). Other examples of accident reduction are given, based on removal of curb parking or change from angle to parallel. Use of parking prohibitions is suggested as a means of reducing pedestrian accidents.

7. Anderson, K. W., "Traffic Engineering to Reduce Accidents," Traffic Engineering, Vol. 39, No. 12, September 1969, pp. 48-53.

Costs related to an average parked car accident were estimated to be $1,700 in 1967. The figures were developed from average awards in Utah courts.

8. Arizona Highway Department, "Traffic Engineering, What, Why, How."

Angle and parallel curb parking effects are described in this public relations pamphlet. Angle parking requires wide streets to reduce interference with through traffic, is more hazardous to both pedestrians and vehicles than parallel parking, and is not allowed on state or federal-aid highways without permission.

A 40% reduction of accidents was reported along a section of U. S. 80 in Yuma where curb parking was removed and left turn bays added within a painted median.

9. Box, P. C., "Accident Characteristics of Non-Arterial Streets," Traffic Digest and Review, Traffic Institute, Northwestern University, Evanston, Illinois, March 1964, pp. 12, 14, 15, 17-19.

This article contains data on parking related accidents on local residential streets --both single family and apartment areas. Midblock accidents of other types and intersection accidents are also discussed. The study covers two years in Skokie, Illinois (pop. 60,000).

Of the minor street accidents reported, 61% were midblock accidents. The continuity of the minor street was found to have little effect upon the accident rate, while street width was found to be an important factor. In all cases, the parked car was consistently found to be a factor influencing the accident rates.

10. Box, P. C., "Major Intersection Improvement --An Urban Example," Public Safety Systems, July 1968, pp. 13-16.

Parking was prohibited along portions of business and residential streets within a six-legged intersection improvement, and parked car accidents dropped from 27 to 3 during a four-year before and after study. (Accidents rose 26% elsewhere within the community during the after period).

11. Box, P. C., "The Curb Parking Effect," Public Safety Systems, January/February 1968, p. 10.

This article reviews curb parking accidents as related to functional classification of streets in a suburban city (pop. 60,000). Types of parking accidents are discussed. Ten percent of all accidents in the city was reported to involve curb parking on six percent of street miles.

A proposed curb parking policy is outlined by the author, including recommendations for enabling legislation to allow cities to condemn property and assess benefitted owners of all types of land (including residential).

12. Burrage, R. H. and Mogren, E. G., "Parking," The Eno Foundation for Highway Traffic Control, Saugatuck, Connecticut, 1957, 401 pages.

A comprehensive discussion of parking practices, concepts, philosophy and state-of-the-art up to the mid 1950's. Accidents, design and effects on street capacity are among important elements examined with regard to curb parking.

Parked cars or parking activity account for about one-tenth of all accidents. Of these, half directly involve the parked car, cars moving from the curb account for the next highest percentage, and cars slowing to park, double-parked or backing involve the rest. Angle parking causes more accidents than parallel. Vehicles parked too close to intersections cause turning accidents and increase congestion. Between 8% to 10% of pedestrian fatalities are caused by emerging from between or behind parked cars.

Banning curb parking increases capacity and allows use of special turn lanes.

Angle versus parallel parking design elements are discussed including vehicle maneuvers, effect on through lane usage, sidewalk encroachment and sight distance factors.

Marking of stalls was reported to reduce parking time to about 22 seconds, down from 38 seconds along unmarked curbs.

Parked cars caused 5.3% rural fatal accidents in 1956. Accident statistics, types of rural parking and design treatments are discussed.

An extensive bibliography was developed.

13. "Statistical Summary, 1973," Chicago Police Department, Chicago, Illinois, 1974, 12 pages.

Traffic accidents are summarized by type for 1973. Vehicles striking parked vehicles caused 2% of fatal, 6% of non-fatal/injury accidents, and 26% of property damage. Overall, parked vehicles were struck in 23% of all Chicago accidents that year.

14. Hoffman, M. R., Lampela, A. A., and Alashara, N., "Evaluation of a Removal of Curb Parking and Conversion to Five Lane Street Operation," Michigan Department of State Highways, Lansing, Michigan, November 1968, p. 12.

The removal of curb parking along 3.25 miles (5.2 km) of a state highway provided an additional fifth lane for left turns. Accidents were reduced 24% (659 to 501), including a parked car accident drop from 48 to 1, in a two years before and two years after study, while traffic volumes increased 32%. A cost benefit analysis of the accident reduction only (delay costs, etc. not considered) showed that a $5,300 project cost provided a $153,000 public benefit in the two-year after period.

15. "Transportation and Traffic Engineering Handbook, 4th Edition," Institute of Traffic Engineers, Washington, D. C., 1976, pp. 110, 119, 338 and 716.

Parked car accidents were included with a 1972 nationwide accident study. Overall, parked cars were involved in 13.1% of accidents (11.3% - one car parked; 0.2% - car entering parked position; 1.6% - car leaving parked position). In urban areas the overall parked car involvement was 16.5%, with 7.6% in rural areas. Parked vehicles caused 1.3% of the fatal accidents overall (1.4% in urban areas, 1.2% in rural areas).

Angle parking is reported to cause five times more accidents than parallel.

Parallel parking reduces effective width by at least 8 feet (2.4 m) as related to capacity and service volumes. Double parking can force traffic to await gaps in opposing traffic on narrow, 2-way streets.

Stalls should be defined by white lines extending perpendicular 7 feet (2.1 m) from the curb; marked with an 'L' for end stalls and a 'T' for interior.

16. "A Guide for Evaluating Parking on Primary Road Extensions," Iowa State Highway Commission, March 1967.

State policy generally discourages curb parking, due to the adverse affect on traffic flow, increased driver tension and accidents (16% of all accidents in urban areas reported). Angle parking is prohibited adjacent to through traffic lanes, because it reportedly is causing up to 50% more accidents than parallel parking.

The guide provides design criteria for parking lanes on new or reconstructed primary highways. Included are parallel arrangements and provision for angle parking physically separated from through traffic by barrier curb channelization. Stall dimensions, parking maneuver space and roadway cross-section elements are illustrated.

17. Marconi, W., "Accident Reduction Through Operational Measures," Department of Public Works, San Francisco, California, 1966, 16 pages.

Study of Park Presidio Boulevard with no parking allowed, showed 2.06 accidents per MVM midblock and 0.43 accidents per million entering vehicles at intersections. A similar route, except with parking allowed (19th Avenue), had a midblock rate of 3.65 accidents per MVM and an intersection frequency of 0.36 per million vehicles.

Another comparison of sections along Geary Boulevard found 2.96 accidents per MVM in blocks with parallel parking versus a 7.12 rate in blocks with angle parking.

18. "Parking Prohibition Reduced Dallas Accidents and Congestion," Traffic Engineering, Vol. 17, No. 1, October 1946, pp. 20-21.

Parking was prohibited on four CBD streets, 4:30 to 6:00 PM, except Sundays and holidays. A 60-day study showed a 26.7% increase in vehicle speeds, 21.6% drop in accidents, with a 100% drop in injuries.

19. Rankin, W. R., "Parking, Chapter 10, Roadway Control and Roadway Elements --Their Relationship to Highway Safety/Revised," Highway Users Federation for Safety and Mobility, Washington, D. C.,1971.

Parking is identified as a factor in 18% to 19% of urban and 5% of rural accidents. The average cost of parking accidents is reported as 54% of the average accident (involvement). Research is recommended on: (1) the relationship of parked vehicle as a fixed object hazard in roadway for various levels of parking density, traffic volumes and speeds; (2) changes in turnover rates on accidents; and (3) layouts to minimize entry-exit maneuvers as related to accidents.

20. Seburn, T. J., "Relationship Between Curb Uses and Traffic Accidents," Bureau of Highway Traffic, Yale University. (Also see Traffic Engineering, Vol. 37, No. 8, May 1967), pp. 42-47.

This is a report on a detailed study of parking, loading, and standing related to accidents.

Data were obtained from 32 cities in 17 states for 95 miles (153 km) of major and collector streets, including nearly 2,200 curb related accidents and 9,500 non-parking accidents. For analysis, accidents were correlated to street segments of uniform character, classification, traffic volume, speeds, parking regulation and characteristics, land use and location (Downtown, Intermediate or Outlying), and similar geometry. Relationships were found among the following variables:

Parking Controls: A small sample size indicated unrestricted parking caused more accidents than locations with parking controls (time limit) or prohibition.

Traffic Volume: Parking accident rates declined slightly as volume increased, while the non-parking accident rate decreased substantially.

Roadway Width: Parking accident rates went down slightly with increased width and non-parking rates went up.

Location: Non-parking accident rates dropped sharply from Downtown to Intermediate to Outlying, while parking accident rates only slightly declined.

21. Smith, W. S., "Influence of Parking on Accidents," Traffic Quarterly, Eno Foundation, Saugatuck, Connecticut, April 1947, pp. 162-178.

Accident statistics from the late 1930's to 1946 are cited. In general, parking activity, including parked vehicles, caused 17% of city and 10% of rural accidents. Only 1.3% urban and 2.5% rural fatals involved parked cars. Between 5% and 6% fatals and 9% injuries to pedestrians were due to parked cars.

Numerous cases of angle versus parallel parking were discussed, with findings that parallel parking reduced accidents by up to 63% when converted from angle, with traffic flow significantly improved.

Double parking was reported to cause up to 17% of accidents to transit vehicles. Increasing corner clearance at intersections reduced (and in one study, eliminated) turning accidents.

Many cases of accident improvement were attributed to total parking prohibition. In mid-town Philadelphia, accidents were reduced by 15% to 20% on 1-way streets where loading was allowed on the right side only (left side by permit). City accidents rose 45% during the same period. Stopping and standing can defeat parking prohibitions and must be strenuously enforced.

Peak period prohibitions were reported to reduce accidents by as much as 88% in one city, and increase average speeds 27% in another.

Road design influences parking accidents. Curbs

should be designed to control parking. Curb height can interfere with door opening and loading activity. Road widths and turnouts can be designed to minimize curb parking interference. Rural and suburban roadways may require shoulders for safe emergency stopping, and for use by school buses and other transit vehicles.

22. "Downtown Parking Study, Mesa, Arizona," Arizona Highway Department, February 1960, 6 pages.

The two-year accident rate was 300% higher for angle parking compared to parallel along a section of U. S. 60 in downtown Mesa. The street is 100 feet (30 m) wide. The angle parking section accident rate ranged from 2.24 to 8.01 accidents per MVM, averaging 4.87. Parallel parking accident rates ranges from 0 to 1.76, averaging 1.42.

23. "Parking Study on State Route 87, Chandler, Arizona," Arizona Highway Department, 1963, 10 pages.

Nine separate locations were studied, involving 70 angle parking spaces. Five years of accident data were included, comparing the first four years to state-wide data. In one year, parking directly caused 14% of the Route 87 accidents in Chandler.

Angle parking is recommended to be converted to parallel, and revised parking layouts are suggested.

24. "Community Guide to Parallel Parking," Utah State Department of Highways, Salt Lake City, Utah, June 1966, 28 pages.

This is a public relations booklet prepared by the State Traffic Engineering Section to encourage parallel parking replacement for angle parking. Accident statistics, design criteria and economic benefits are highlighted.

An accident study cited involving 9 Utah cities showed a 25% overall accident reduction, 31% decrease in injury/fatal, and 57% less parking type accidents with parallel parking as compared to angle. Dollar

losses due to accidents and injuries decreased by 29% as did the accident rate per million vehicles. Out-of-state studies in Kansas City and Oakland are referenced, which found 50% to 65% fewer parallel parking accidents compared with angle parking.

Up to 50% less street space is used, according to design data.

An economic study found that after a temporary dip, retail sales climbed to record high levels after angle parking was converted to parallel.

Statements supporting parallel over angle parking are reported from a number of Utah cities and from 33 states.

25. Crandall, F. B., "Parallel Parking 65% Less Hazardous Than Angle Parking," Virginia Highway Bulletin, July 1948, p. 9.

Salem, Oregon study of two business blocks, each street 59 feet (17.9 m) wide with 7,500 ADT. Four-year study (1941-45) found 57 accidents on streets with angle parking, due to the parking. There were 20 other accidents on the street, for a total of 77 accidents.

The second street with parallel parking had 20 accidents due to parking, plus 16 other accidents for a total of 36.

26. Fisher, G. J., "Angle vs. Parallel Parking," Traffic Engineering, Vol. 21, No. 1, October 1950, pp. 15, 21.

Angle parking was converted to parallel parking along a 1½ mile (2.4 km) section of a 65 foot (20 m) street in a business area. In a three-month study, vehicle speed increased from 12 MPH (19 KPH) to 16 MPH (26 KPH), peak period volume increased from 900 to 1,200 vehicles per hour, and accidents dropped over one-third.

27. Johnston, B. K., "Angle vs. Parallel Curb Parking: Time and Street Width Required for Maneuvering,"

Division of Transportation Engineering, University of California, Berkeley, 1960.

This article reports a study of one block face with angle parking at 37.5° and 7.5 feet (2.2 m) stall width, and one block face of parallel parking with 20 feet (6 m) stall length. A sample of 177 angle unparking maneuvers and 105 parallel parking maneuvers were obtained. Findings were:

1. Angle parking - 12 seconds required

2. Parallel parking - 32 seconds required

3. Street width to maneuver w/angle - 26.1 feet (7.8 m) including parking area

4. Street width maneuver w/parallel - 17.8 feet (5.4 m) including parking area

5. Street width affected by parking, including adjacent lane clearances was:

   Angle 19.1 feet (5.9 m)
   Parallel 10.3 feet (3.2 m)

6. Adjacent lane vehicle clearance from edge of parked car was:

   Angle 5.0 feet (1.5 m)
   Parallel 3.2 feet (0.9 m)

7. Street area used when parked including adjacent lane clearance was:

   Angle 238 square feet (22 sq.m)
   Parallel 204 square feet (19 sq.m)

28. "Abilene Traffic Operations Plan," Pinnell-Anderson-Wilshire and Associates, Inc., Dallas, Texas, 1975, 125 pages.

Traffic operations in the City of Abilene were

analyzed to identify problems of safety and congestion and to make recommendations for their alleviation. Conventional traffic operation parameters were utilized.

Of 1,527 curb parking spaces in the CBD, 1,318 are angle parking and 209 parallel spaces. Average accident rates per mile of street were 5.4 for angle versus 1.4 for parallel parking. Accident rates per 10 MVM on these streets were 28.4 for angle and 11.6 for parallel parking. Based upon these data, the removal of all angle parking was recommended.

29. Berger, W. G. (Vol. 1) and Knoblauch, R. L. (Vol. 2), "Urban Pedestrian Accident Countermeasures," Bio Technology, Inc., DOT report, available NTIS-HS-801-346.

(Volume 1) - Effectiveness of nine proposed countermeasures was tested by behavioral studies of 16,000 pedestrians in 8 cities. Interviews were made with 2,100 pedestrians and 200 residents or merchants. Speed checks of 35,000 vehicles were made. Analysis found 17 of 30 tested behaviors to be significantly modified by the countermeasures.

The study of angle parking as a countermeasure involved only 77 observations in Miami and 22 in San Diego. The Miami site was a 34 foot (10.2 m) wide, 1-way street, converted to 12 spaces on one side, at 30 degrees, with no parking on the other side. The original two lanes of traffic, plus two parking lanes was reduced to one moving lane plus the parking lane. Abutting land use consisted of stores and apartments. The San Diego street was 30 feet (9 m) wide, 2-way with unrestricted parallel parking. It was converted to 1-way operation, with 26 angle spaces marked at 45 degrees and no parking on the other side. Land use was mixed single and multi-family.

Interviews with 15 residents in the San Diego experimental block found the following: one-third felt accidents would decrease; one-third were undecided; and two-thirds complained about the angle parking. No interviews were conducted in Miami.

(Volume 2) - Data were especially collected on

characteristics of 2,044 pedestrian accidents from 6 cities. Samples ranged from 2% (New York City) to 100% (San Diego) of reported pedestrian accidents during 1973 in these cities. The average sample was 10%. Findings were compared with prior Operations Research Institute study in certain categories. Parking-related findings include:

61% of accidents were in midblock.
43% of accidents were on 2-lane street.
31% of accidents were on 4-lane street.
43% of accidents happened in parking lane.
16% of accidents involved vision blocked by parked car.
19% of accidents involved pedestrian crossing from behind parked car.
28% of accidents occurred at night.
75% of accidents occurred on 2-way surface streets.
43% of accidents occurred in fully residential areas.
25% of accidents occurred in mixed commercial areas.

30. "Pedestrian Accidents in New York State," Statistical Bulletin No. 1 (63), Department of Motor Vehicles, State of New York, 1963, 8 pages.

Of 786 pedestrians killed and 25,406 injured in 1962, those coming from behind parked cars were killed in 63 accidents and were injured in 4,880 accidents.

31. Walsh, L. B., "Pedestrian Safety for Urban Streets," San Jose Department of Public Works, NHTSA Contract No. PB-225 435, 1972, 433 pages and Appendix.

This study reports that 20% of pedestrian accidents involved coming from behind a parked car. Driver vision was reported obscured by parked cars in 22% of pedestrian accidents.

32. Yaksich, S., "A Study of Pedestrian Fatalities in Washington, D. C., 1948-1957," Traffic Engineering and Safety Department, American Automobile Association, Washington, D. C., 1958, 25 pages.

Two-thirds of all pedestrian fatals occurred be-

tween intersections. More than one-half of all school age child pedestrians killed in traffic were stepping from between parked cars.

33. Berry, D. S. and Verge, M. F., "Optimum Width for Widening Secondary Arterial Streets," Highway Research Board Record 83, Transportation Research Board, Washington, D. C., 1965, pp. 45-47.

    A method for determining speeds and positions of vehicles on streets with parking on one or both sides is discussed, with comparative data for free moving, meeting and other vehicle maneuvers tabulated. Criteria for determining effective street width are given.

34. "Effect of Rush Hour Parking Control on Street Traffic and Transit Operation," unpublished study by Chicago Transit Authority, 1949, 11 pages.

    One year before and after speed studies evaluated the effects of rush hour (7-9 AM and 4-6 PM) parking bans on some of the streets served by the CTA.

    Traffic volumes increased by as much as 51%. Auto speed increased from 25% to 47%, and transit speeds increased from 3% to as much as 16%. Transit vehicles completing trips late dropped by 40% to as much as 70% on some routes.

    Streetcar-auto accidents dropped within a range of 25% to 35% during rush hours on two streets.

35. Gallagher, J. A., "Driver Characteristics in Parallel Parking on One-Way Streets," Traffic Engineering, Vol. 20, No. 7, April 1950, pp. 276-279.

    This study reported on left side versus right side parallel curb parking maneuver time for 20 foot (6 m) metered stalls. The sample was 200 for each type. Average times were left side 33.8 seconds, right side 37.9 seconds. Time was reduced for longer maneuver areas, with right side parking times generally greater for each area checked.

Only two maneuvers were required for 53% of left side parkers versus 38.5% of right side parkers.

Average distance, curb to wheels was 0.75 feet (0.23 m) left side and 0.43 feet (0.13 m) right side.

Average distance parked from car in front was 3.6 feet (1.1 m) left side and 3.7 feet (1.1 m) right side.

Average distance parked from car behind was 3.1 feet (0.9 m) left side and 3.5 feet (1.0 m) right side.

Average length of cars was 16.4 feet (4.9 m).

36. Hoose, H. J., "Peak Hour Parking Restrictions and Reversible Lanes in Central Business District," Unpublished, undated.

Curb parking was removed during morning and evening rush periods, improving traffic flow and reducting accidents. Along two major, 60 foot (18 m) wide CBD streets, curb parking was banned from 7:30 to 9:30 AM and 4:30 to 6:30 PM. Center lane volume increased as much as 78%, overall delay dropped by 25%, operating speed and transit operating efficiency improved by 15%. The transit accident rate dropped to 0 in the parking ban area.

37. Kell, J. H. and Johnson, B. C., "Optimizing Street Operations Through Traffic Regulations and Control," National Cooperative Highway Research Program Report 110, Transportation Research Board, Washington, D. C., 1970, p. 100.

Existing traffic conditions were measured in the CBDs of two cities, and used to evaluate changes in operations including removing curb parking (enforced by towaway) on major streets, and providing angle curb parking along nearby side streets. Signal timing changes, turn prohibitions and 1-way streets were also implemented.

Various combinations of controls and regulations were measured by speed and delay studies, accidents were monitored, and each combination was related to driver observance, public acceptance and business performance.

Studies were made of parallel parking times of flow obstruction (time of parking maneuver during which adjacent through lane flow was affected), of total parking maneuver (begin backing until final positioning), and the cumulative distance of curb to wheels, for three types of parking. Results were:

Stall Pattern	Flow Obstruction Time (sec.)	Total Parking Maneuver Time (sec.)	Cumulative Distance, Curb
Unmarked	4.9	12.9	14.8" (38cm)
24 ft. (7.2 m)	9.9	32.5	20.0" (50cm)
Tandem 20 ft.-20 ft.-8 ft. (6 m -6 m -2.4 m)	11.0	20.7	21.6" (54cm)

38. May, A. D., "Solving Our Parking Problems," Public Works, Vol. 89, No. 5, May 1958, pp. 100-104.

A discussion of parking inventory techniques and needs. General comments on the effects of curb parking were made by the author. One such comment was that parallel parking on a 2-way, 45 foot (13.5 m) wide downtown street reduces capacity by 90%.

39. Normann, O. K. and Walker, W. P., "The Effect of Curb Parking on Street Capacity," Traffic Engineering, Vol. 17, No. 8, May 1947, pp. 332-334.

Data at 300 intersections were analyzed as part of the initial work that would be used later in the Highway Capacity Manual. One significant finding was that curb parking had lesser effect on capacity in intermediate areas (35% as compared to an average 45% reduction in capacity in the CBD.

40. Tufte, E. E., "Curb Parking is Culprit," Public Works, Vol. 98, No. 3, March 1967, pp. 104-105.

Curb parking was allowed on a 70 foot (21 m) wide street, leaving only four moving traffic lanes, blocked much of the time by left turns (inside lane) and parking activity. Parking was prohibited 7-9 AM and 4-6 PM.

Parking was then prohibited from 7 AM to 7 PM, a separate, 9 foot (3 m) center left turn lane was added, with three moving lanes in each direction (2 when parking allowed). Travel speed increased from 12 MPH (19 KPH) to 17 MPH (27 KPH), and average delay was reduced as much as 50%, mostly in the center lane (relief of left turn congestion). Property damage accidents dropped by 38%, but fatal and injury accidents remained unchanged (93 before to 91 after).

41. Webster, L. A., "A Simulation Study of the Effect of Curb Parking Maneuvers on Midblock Traffic Delay on Urban Arterial Streets," Ph.D. Dissertation, Civil Engineering Department, University of Illinois, Urbana, Illinois, 1968, 120 pages.

The frictional effect of curb parking maneuvers on traffic flow was modeled and the simulation analyzed by a digital computer. The model assumed cars could not cross the centerline, with a 12 foot (3.6 m) wide through lane and 8 foot (2.4 m) wide parking lane, along a 660 foot (200 m) long block providing twenty, 22-foot (6.6 m) long parallel spaces.

The research included simulation of three levels of service and seven turnover rates. Results indicated that average delay to through vehicles and the percent of such vehicles delayed varied with the three levels of service, but not with the seven turnover rates.

In addition to computer simulation, some field data was collected for validation, and 77 references are cited in the bibliography.

42. "Paired-Off Parked Cars Speed Traffic Flow," Illinois

Municipal Review, December 1951, p. 232.

References Whittier, California use of 18 foot (5.4 m) curb spaces, spearated by 8 foot (2.4 m) red zone for maneuvering.

43. "Parking in Residential Areas," National Committee for Traffic Safety, Building Traffic Safety into Residential Developments, 1949, pp. 25-29.

Discusses angle parking bays for apartment or row-houses, recessed 20 feet (6 m), but with sidewalk setback to clear parking curb by 2 to 3 feet (0.6 to 1.0 m). Should not be used in single family area or with through or high volumes. Enclosed 90 degree parking bay setback 44 feet (13 m) plus sidewalk clearance and including 4 foot (1.2 m) separator island can be used on feeder (collector) streets. Danger to children playing in maneuver areas.

44. Stover, V. G., Adkins, W. G. and Goodknight, J. C., "Guidelines for Medial and Marginal Access Control on Major Roadways," NCHRP Project #3-13, Final Report, Texas Transportation Institute, 1969, pp. C-22-23.

Parking near driveways affects vehicle turning path and driver sight distance. Parking prohibition is recommended within 50 feet (15 m) of driveways.

Also recommended is a "paired" parallel parking arrangement (for ease of access) with stall widths of 12 feet (3.6 m) to provide satisfactory clearance for through traffic.

45. Taylor, Brainerd O., "Parking Sceme Cuts Maneuvering Time," Public Works, Vol. 106, No. 5, May 1975, pp. 77-79.

A discussion of a parallel parking design providing for a 16 foot (4.8 m) maneuver area between a pair of adjacent 20 foot (6.0 m) stalls. Access to either an upstream or downstream stall can be achieved by a pull-in maneuver requiring an average of about 4 seconds time. Back-up into conventional parallel curb

parking averages 32 seconds, and may be longer if the first maneuver is misjudged. Traffic flow can be improved, particularly if parking is along a street with a progressive traffic signal system.

The arrangement reduced the number of spaces 14% on the two blocks where this configuration was installed.

46. _____, "Twin-Stall Curb Parking at Monterey Park (California)," Western City, February 1951, 36 pages.

Paired curb parking layout in this city uses 20 foot (6.0 m) stalls with 11.75 foot (3.6 m) no parking zone for maneuver between each pair. Location was four blocks long in business areas.

47. Williams, A., "Parking Bays," ITE Proceedings, Western Section, 1966.

Parking is allowed in an 8 foot (2.4 m) wide bay, if sufficient right-of-way is available (or dedicated) to allow an adjacent 5 foot (1.5 m) sidewalk. The curb in the bay is connected on a 45° angle to the main street curb, with radii to allow easy maneuver by street sweepers. Straight curb bay lengths are: 25 feet (7.6 m) for 1 stall; 55 feet (16.5 m) for 2 stalls; 77.5 feet (23.5 m) for 3 stalls; and 100 feet (30 m) for 4 stalls.

No accidents were reported caused by facilities in use up to one year along commercial streets.

48. "State Highway Department Policy on Parallel Versus Diagonal Parking," American Association of State Highway Officials, AASHO Proceedings, 1950, pp. 386-387.

State highway department policies on angle and parallel parking are listed by widths of road and degree permitted in 1950.

49. Barr, W. G., "The Use of Public Streets as Parking Lots," Parking, National Parking Association, Fall 1963, pp. 14-15.

Objections to curb parking (in addition to congestion) identified as:

1. Contributes substantially to total number of accidents.

2. Contributes substantially to number of intersection accidents by restricting visibility.

3. Parked car is a vital factor in occurrence of pedestrian accidents, particularly those involving children, by restricting visibility of both the motorist and the pedestrian.

4. Accidents are caused by persons entering and leaving parked cars.

5. Curb parking hampers street maintenance, sweeping and snow removal.

6. Vehicles parked at curb frequently restrict emergency vehicles and operations.

7. Problems created by car breakdowns, emergency stops, loading and unloading of freight and passengers are complicated by curb parking.

Suggested considerations and policies for present and future are:

1. Streets should have been designed in the past, and should be in the future, for vehicular travel and not parking.

2. The total cost to a community for storage of vehicles on the street is enormous --taking into consideration the cost of accidents, cost of capacity restrictions, delays and other costs.

3. Curb parking restricts capacity more than most people realize.

4. Curb parking on our major streets must

inevitably be eliminated in the future, in view of estimates of auto registration and travel.

5. If curb parking must ultimately be removed, even on widened or improved streets, should not policy of waiting until volumes build up to capacity be changed?

50. Cameron, W. E., "On-Street Parking," Proceedings, Road Builders Clinic, State College of Washington, Pullman, 1958, pp. 101-102.

Discussion of angle vs. parallel curb parking and the California Division of Highways policy to prohibit use of gas tax funds for new construction on any street where angle parking is allowed.

51. Box, P. C., "Regulation of Curb Parking and Loading Zones, Parts I and II," Public Safety Systems, November/December 1969 and January/February 1970.

Recommended policy is presented on curb parking prohibition criteria in midblock sections at controlled intersections, related to volume per hour per lane. Details are included on study techniques for local residential streets to determine where parking restrictions and/or 1-way postings should be used.

Data are listed from other studies of accident hazards related to parking.

52. Box, P. C., "The Importance of Street Classification in Traffic Design and Control," Public Safety Systems, March/April 1968, p. 10.

The author discusses the necessity of establishing whether curb parking is to be allowed, by type of street (major, collector or local), when specifying design standards for roadway and right-of-way widths. A policy is suggested for major route curb parking whereby abutting land owners would be assessed full construction cost of added width required, 8 to 10 feet (2.4 to 3 m) each side.

53. Box, P. C., "Traffic Control at Minor Intersections," Municipal Signal Engineer, January/February 1966, p. 21.

Parked cars as they affect sight distance are cited as a factor to consider in the evaluation of minor intersection traffic control. Uncontrolled and Yield sign controlled intersections are critical.

54. Burton, H., "Municipal Parking Policies," Canadian Good Roads Association Proceedings, 1961, pp. 448-456.

Recommends policy that:

1. Curb parking or standing be eliminated as required to avoid undue congestion of traffic.

2. Off-street parking be provided to the extent that users of the space are prepared to pay an economic rent for the space occupied.

3. Where curb parking is permitted, it should be on the same basis of an economic rent which, because of the convenience to the user and the cost to the taxpayer, should be as high or higher than adjacent off-street rents.

55. Dorsey, R. T., "Techniques of Reducing Congestion at City Street Intersections," Proceedings, First California Institute on Street and Highway Problems, University of California, Berkeley, 1949, pp. 157-160.

The author states that parking should be prohibited 25 feet (7.5 m) on approaches to signalized intersections, to expedite right-turning movements and increase visibility. Parking should be fully banned one block either side of such an intersection when traffic volumes are at capacity.

56. Goodwin, C. A., "Truck Loading Facility as Related to Parking," Traffic Engineering, Vol. 20, No. 5, February 1950, pp. 189-192.

Discussion of need for loading zones to avoid

indiscriminate loading practices, including double parking and blockage of alleys and driveways. Standards are suggested, such as; Curb length; 25 feet (7.5 m) minimum or 30 feet (9 m) desirable, or multiples thereof.

Warrants; a. No alley or off-street dock available.

b. Minimum of 12 stops per day.

c. Average weight, 500 pounds (230 kg), average of 10 pieces per stop.

d. Over 50% of commercial vehicles with capacity of 4 tons (3,600 kg) or more.

Restrictions and determination of need of above discussed.

Narrow streets 30 feet (9 m) or less, served by trucks should have parking prohibited, at least on one side.

57. Heyman, J. H., "Parking Trends and Recommendations," Traffic Quarterly, Vol. XXII, No. 2, April 1968, pp. 245-257.

General comments on curb parking were included with discussion on parking trends, needs and policies.

Curb parking contributed to 17% of the accidents in some Connecticut communities. Other comments related to capacity reduction, restricted sight distance at corners, the forcing of people to exit from cars into the street --creating pedestrian accident potential-- and the hampering of street maintenance and emergency vehicle use.

58. "Policy of Curb Parking," Proceedings, Institute of Traffic Engineers, 1955, pp. 187-192.

A report on the draft of the 'policy'. Curb parking stall widths were suggested at 8 feet (2.4 m) for cars, 9 feet (2.7 m) for commercial vehicles.

A table of minimum street widths was related to one or two-side parking, and qualified by commercial vehicle use (15% or more required a wider street).

Other considerations included prohibition if street capacity was affected, providing for transit loading zones, clearance from fire plugs - 30 feet (9 m), driveways - 8 feet (2.4 m), and intersection sight distance evaluation, based on an engineering study. Curb parking was recommended to be banned adjacent to schools and playgrounds for child safety.

59. "Recommended Practices for Subdivision Streets," Traffic Engineering, Vol. 34, No. 12, Institute of Traffic Engineers, September 1964.

This publication discusses relations of residential curb parking to street width, type of curbing, and density of land use.

60. "Local Street Parking Criteria," Technical Committee 3F (64), Traffic Engineering, Institute of Traffic Engineers, March 1967, pp. 32-33.

The proposed recommended practice was developed as a guide to define elements and suggest warrants for parking controls and 1-way streets. Parking elements included:

1. Accident Experience - 24 to 36 month period with significant numbers of parking, driveway, head-on and sideswipe accidents; No Parking recommended.

2. Lane Width - A figure illustrates minimum and desirable parking (1 or 2 side or total ban) related to 1-or 2-way operation.

3. Curvature and Grade - No Parking is recommended on inside of a 300 foot (90 m) or less horizontal curve, or on one side of a street with vertical crest sight distance less than 160 feet (50 m), on a street more narrow than 36 feet (11 m).

4. Other factors, including street maintenance and local zoning codes, as evaluated with engineering judgment.

61. Skinner, H. B., "Pavement Markings," Highway Research Board Special Report 93, Proceedings, Improved Street Utilization Through Traffic Engineering, Washington, D. C., May 1967, p. 55.

City of Denver pavement marking policy provides for an outside parking lane, which is adjacent to parked vehicles and which includes sufficient width to accommodate both a moving vehicle and a parallel parked vehicle. Minimum is 17 feet (5.1 m) and desirable is 19 feet (5.7 m).

62. "TOPICS Study, Anchorage Metro Area Transportation Study," Wilbur Smith and Associates, Columbia, South Carolina, 1969, 79 pages.

Curb parking removal was recommended along several CBD streets (one or both sides) to improve traffic flow. Recommendation was also made to prohibit parking 30 feet (9 m) from intersection approaches in order to provide adequate sight distance.

63. Wilson, B., "Minimum Width for Residential Streets," Rural and Urban Roads, Vol. 3, No. 2, February 1965, pp. 56-57.

The author suggests a minimum width of residential street with parking on one side as 27 feet (8.1 m) and with parking on both sides as 34 feet (10.2 m). A desirable width for both side parking and 2-way traffic would be 40 feet (12 m).

64. Bruening, M. F. and Wantoch, H. J., "Milwaukee's Parking Program," Traffic Quarterly, Eno Foundation, Saugatuck, Connecticut, January 1964, pp. 30-47.

All-night curb parking was allowed by permit, interim to providing off-street parking facilities in residential areas. Alternate side parking (even ad-

dress side on even days, odd address side on odd days) was required for street cleaning, crime detection, and general maintenance purposes.

A $4.00 annual fee was used for off-street parking construction and maintenance.

An example of parking policy was included.

65. Box, P.C., "Intersections, Chapter 4, Traffic Control and Roadway Elements --Their Relationship to Highway Safety/Revised," Highway Users Federation for Safety and Mobility, Washington, D. C., 1970.

In urban areas, 40% to 60% of accidents were reported as intersection-related.

66. Box, P.C., "Driveways, Chapter 5, Traffic Control and Roadway Elements - Their Relationship to Highway Safety/Revised," Highway Users Federation for Safety and Mobility, Washington, D.C., 1970.

Summarizes accidents related to driveways including findings that such collisions typically involve 11% to 14% of accidents.

APPENDIX B. MATERIAL DISCUSSED OR REFERENCED IN STREET AND ACCIDENT DATA COLLECTION

Definitions of Street Classifications/Pedestrian Activity.

Figure B-1, Field Check Sheet.

Figure B-2, Coding of Field Sheet.

Calculation of Annual Space Hours.

Figure B-3, Residential Curb Parking Variation by Hour.

Figure B-4, Accident Data Tabulation Sheet.

Figure B-5, Coding of Accident Data Tabulation Sheet.

Table B-1, 1-Way Street Miles by Width.

Table B-2, 2-Way Street Miles by Width.

Table B-3, Street Miles by Parking Regulations and Functional Classifications.

Table B-4, Selected Area Midblock Accidents by Severity, Street Classification and Parking Involvement.

Table B-5, Selected Area Intersection Accidents by Severity, Street Classification and Parking Involvement.

Definitions of Street Classifications

Major: A primary route for intra-city vehicular movement, generally connecting areas of significant traffic generation, and characterized by high traffic volumes (generally above 5,000 vehicles per day), commercial traffic, highest speeds of unlimited access city streets, and frequent abutting commercial land use. Trip lengths are typically a mile or more.

Collector: A secondary street for vehicular movement, with branching, intersecting local streets. Volumes are moderate and typically in the range of 1,000 to 4,000 vehicles per day. The collector street serves to transfer traffic between the local streets and the nearest major streets. Trip lengths are short; usually averaging less than one-half mile.

Local: A street whose primary function is to serve abutting land use. Trip lengths are usually very short (a few blocks). Volumes depend on the nature of land use, and seldom exceed a few hundred vehicles per day for residential use.

Pedestrian Activity

Pedestrian activity is related to land use. The classification by land use, as a surrogate for pedestrian volumes, has been long established in national practice. The Illuminating Engineering Society Recommended Practice for Roadway Lighting has, since 1963, used such a system. (Prior to this, pedestrian estimates had been required to specify illumination needs). A similar system of land use/pedestrian relationship is defined in reference 2, page 19.

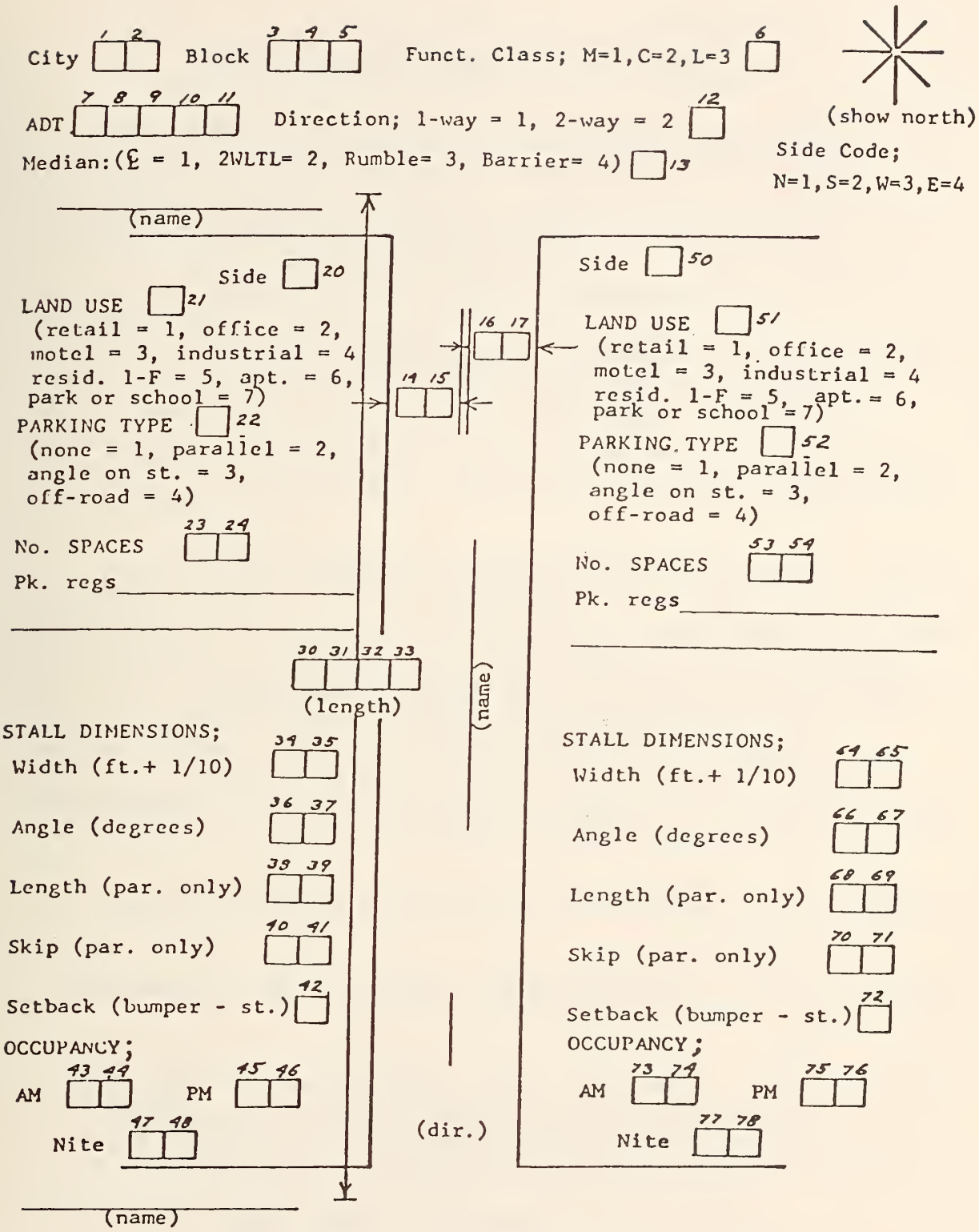

City 1 2
Block 3 4 5
Funct. Class; M=1, C=2, L=3 6
ADT 7 8 9 10 11
Direction; 1-way = 1, 2-way = 2 12
Median: (℄ = 1, 2WLTL= 2, Rumble= 3, Barrier= 4) 13
(show north)
Side Code; N=1, S=2, W=3, E=4
(name)
Side 20
LAND USE 21
(retail = 1, office = 2, motel = 3, industrial = 4 resid. 1-F = 5, apt. = 6, park or school = 7)
PARKING TYPE 22
(none = 1, parallel = 2, angle on st. = 3, off-road = 4)
No. SPACES 23 24
Pk. regs
16 17
19 15
Side 50
LAND USE 51
(retail = 1, office = 2, motel = 3, industrial = 4 resid. 1-F = 5, apt. = 6, park or school = 7)
PARKING TYPE 52
(none = 1, parallel = 2, angle on st. = 3, off-road = 4)
No. SPACES 53 54
Pk. regs
30 31 32 33
(length)
(name)
STALL DIMENSIONS;
Width (ft.+ 1/10) 34 35
Angle (degrees) 36 37
Length (par. only) 38 39
Skip (par. only) 40 41
Setback (bumper - st.) 42
OCCUPANCY;
AM 43 44
PM 45 46
Nite 47 48
(dir.)
STALL DIMENSIONS;
Width (ft.+ 1/10) 64 65
Angle (degrees) 66 67
Length (par. only) 68 69
Skip (par. only) 70 71
Setback (bumper - st.) 72
OCCUPANCY;
AM 73 74
PM 75 76
Nite 77 78
(name)

Figure B-1. Field Check Sheet

1-2, code designation for each city.

3-5, block designation for each study section.

6, functional classification of route (major street = 1, collector street = 2, local street = 3).

7-11, average daily traffic of section where available.

12, direction of flow (1 = 1-way, 2 = 2-way).

13, type of median, if any (painted centerline = 1, 2-way left turn lane = 2, rumble strip = 3, barrier median = 4).

20/50, side of street (north = 1, south = 2, west = 3, east = 4).

21/51, land use codes as shown, 1 through 7.

22/52, parking types as shown.

23-24/53-54, number of legal spaces each side. (Parking regulations coded separately by University of Tennessee).

30-33, length of section, centerline of cross street to centerline of cross street, in feet.

34-41/64-71, dimensions of painted pavement parking stalls.

42/72, setback, average bumper line to edge of traveled way.

43-48/73-78, numbers of cars found parked on each side of each block during each of the three parking checks.

Figure B-2. Coding of Field Sheet

Calculation of Annual Space Hours

In March 1963, a special survey was made of curb parking along approximately 17 miles (27 km) of local residential streets in Skokie, Illinois.* The sample included 5.6 miles (9.0 km) of moderate density, 55 foot (17 m) lot frontage development; 8 miles (12.9 km) of higher density, 45 foot (14 m) lot frontages; and slightly over 3 miles (4.8 km) of apartment areas (typical 3-story). Curb parking checks were made each hour for 24 consecutive hours. A total of more than 33,000 parked cars were tabulated. Figure B-3 is a graph showing the variation in residential curb parking by hour. The values are expressed as a percentage of the 24-hour total.

The average number of cars parked during the overnight period, the morning period, and the afternoon period were summed. This value was divided into total number of parked cars, recorded for the 24 hours; i.e., the summation of the numbers found on each hourly check. The resulting multiplier ranged from 8.6 to 9.7 as residential land use density increased. The average of 9.4 was representative of the denser single family development with 45 foot (14 m) lots.

*Source: Box, Paul C., Director of Engineering, Skokie, Illinois, unpublished field studies.

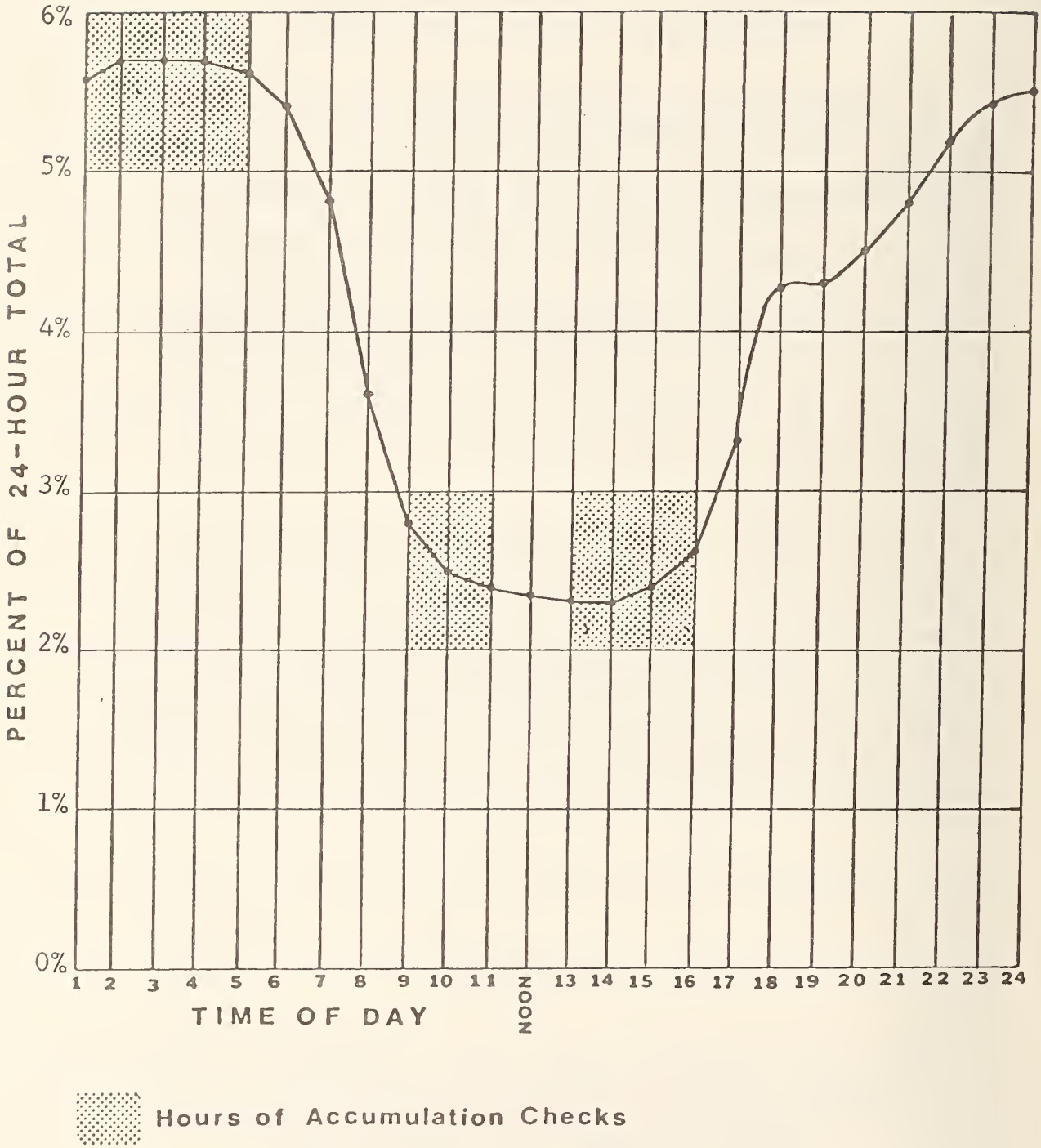


Figure B-3. Residential Curb Parking Variation by Hour

City: [1 2] Block: [3 4 5] Side: [6]

Month: [7 8] Year: [9 10]

Severity: PDO = 1, Injury = 2, Fatal = 3 [11] Location: Intersection = 1, Midblock = 2 [12]

Type of Accident: [13] PK. Involvement [14]

City: [21 22] Block: [23 24 25] Side: [26]

Month: [27 28] Year: [29 30]

Severity: PDO = 1, Injury = 2, Fatal = 3 [31] Location: Intersection = 1, Midblock = 2 [32]

Type of Accident: [33] PK. Involvement [34]

City: [41 42] Block: [43 44 45] Side: [46]

Month: [47 48] Year: [49 50]

Severity: PDO = 1, Injury = 2, Fatal = 3 [51] Location: Intersection = 1, Midblock = 2 [52]

Type of Accident: [53] PK. Involvement [54]

City: [61 62] Block: [63 64 65] Side: [66]

Month: [67 68] Year: [69 70]

Severity: PDO = 1, Injury = 2, Fatal = 3 [71] Location: Intersection = 1, Midblock = 2 [72]

Type of Accident: [73] PK. Involvement [74]

SIDE OF STREET CODE

North	1
South	2
West	3
East	4
N.A.	5

ACCIDENT TYPE CODE:
(Veh.= Moving, P.C. = Parked)

Veh.- Veh on St.	1
Veh.- Veh @ Dr.	2
Veh.- F. O.	3
Veh.- P.C.	4
Veh.- Ped.	5
Veh.- Bike	6
Misc.	7

PARKING INVOLVEMENT CODE:

Stationary	1
Parking	2
Unparking	3
Open Door	4
Sight Restriction	5

Figure B-4. Accident Data Tabulation Sheet

1-6, same as basic field sheet codes.

7-11, month, year and severity as shown on form.

12, intersection or midblock related. (An accident involving a vehicle turning at an intersection and striking a fixed object or parked car also was considered as intersection).

13, accident type:

- 1 = moving vehicle striking another vehicle standing or moving on roadway.
- 2 = moving vehicle striking moving or standing vehicle entering or leaving driveway or alley.
- 3 = moving vehicle striking fixed object.
- 4 = moving vehicle striking stationary parked car including parking/unparking operation.
- 5 = moving vehicle striking pedestrian.
- 6 = moving vehicle striking bicycle rider.
- 7 = all other accidents.

14, parking involvement (coded only when a stationary parked vehicle was struck, or involving a parking action, or where a parked vehicle was reported as affecting sight distance of a driver):

- 1 = stationary parked car struck by moving vehicle.
- 2 = moving vehicle in act of parking or stopping to park.
- 3 = moving vehicle unparking (a parking or unparking vehicle striking a stationary parked vehicle was coded as accident type 4, parking type 2 or 3).
- 4 = collision with open door of adjacent parked vehicle (this code was used for a vehicle in the through traffic lane striking the open door of a parallel parked car, or a vehicle involved in angle parking or unparking striking an open door of an adjacent angle parked car).
- 5 = sight restriction caused by curb parked vehicle. For Involvement 5 accidents, this concerned pedestrians coming from behind parked car.

Figure B-5. Coding of Accident Data Tabulation Sheet

Table B-1. 1-Way Street Miles* by Width

Width, feet**	Miles of Streets			
	Major	Collector	Local	Total
under 21	0	0	0	0
21-22	0	0	0	0
23-24	0	0	0	0
25-26	0	0	0	0
27-28	0.94	0.10	1.77	2.81
29-30	0	0	0	0
31-32	0	0	0	0
33-34	0.11	0	0.22	0.33
35-36	0.53	0.09	0	0.62
37-38	0	0	0	0
39-40	1.62	0.70	0	2.32
41-42	0.29	0	0	0.29
43-44	0.77	0	0	0.77
45-46	0.40	0	0	0.40
47-48	0.43			
49-50	2.83			
51-52	0.36			
53-54	0			
55-56	2.08			
57-58	0	0.28	0	6.31
59-60	0			
61-62	0			
63-64	0			
65-66	0			
67-68	0.33			
TOTAL	10.70	1.17	1.99	13.86

*1 mile = 1.61 kilometers

**1 foot = 0.3 m.

Table B-2. 2-Way Street Miles* by Width

Width, feet**	Miles of Streets			
	Major	Collector	Local	Total
under 21	0	0.16	4.34	4.50
21-22	0	0	0	0
23-24	0.11	0	10.28	10.39
25-26	0	0	6.39	6.39
27-28	0.57	0.21	10.82	11.60
29-30	0.43	0.88	14.89	16.20
31-32	0	0.10	11.53	11.63
33-34	0.29	0.34	11.04	11.67
35-36	1.21	1.74	18.21	21.16
37-38	0	0.20	0.58	0.78
39-40	4.54	8.84	13.61	26.99
41-42	3.27	0	0.50	3.77
43-44	4.89	0.80	0.89	6.58
45-46	0	0.14	1.99	2.13
47-48	0.66			
49-50	1.42			
51-52	0.08			
53-54	0.36			
55-56	2.53			
57-58	0			
59-60	5.42			
61-62	0.26	4.72	1.02	22.81
63-64	0.41			
65-66	0			
67-68	0.64			
69-70	3.08			
71-76	1.46			
over 76	0.75			
TOTAL	32.38	18.13	106.09	156.60

* 1 mile = 1.61 kilometers

**1 foot = 0.3 meters.

Table B-3. Street Miles* by Parking Regulations and Functional Classifications

Regulations	Major	Collector	Local	Total	Proportion
Unlimited	16.94	16.10	101.69	134.73	79%
1-side time limit	0.72	0.21	0.46	1.39	1%
Both side time limit	10.07	1.17	1.49	12.73	7%
1-side prohibitions	4.13	1.30	4.15	9.58	6%
Both prohibitions	11.19	0.51	0.31	12.01	7%
TOTAL	43.05	19.29	108.10	170.44	100%

* 1 mile = 1.61 kilometers

Table B-4. Selected Area Midblock Accidents* by Severity, Street Classification and Parking Involvement (2-Way Streets)

Street Class	Severity: PDO Other	PDO Parking Involved	PDO Sub-Total	Injury Other	Injury Parking Involved	Injury Sub-Total	TOTALS Other	TOTALS Parking Involved	TOTAL	Proportion Parking Involved
Local	27	72	99	9	10	19	36	82	118	69%
Collector	2	32	34	4	4	8	6	36	42	86%
Major	300	238	538	100	19	119	400	257	657	39%
TOTAL	329	342	671	113	33	146	442	375	817	46%

*Areas where all accidents were tabulated --midblock and intersection.

Table B-5. Selected Area Intersection Accidents* by Severity, Street Classification and Parking Involvement (2-Way Streets)

Street Class	Severity: PDO Other	PDO Parking Involved	PDO Sub-Total	Injury** Other	Injury** Parking Involved	Injury** Sub-Total	TOTALS Other	TOTALS Parking Involved	TOTAL	Proportion Parking Involved
Local	39	5	44	17	1	18	56	6	62	10%
Collector	24	2	26	8	0	8	32	2	34	6%
Major	790	19	809	332	3	334	1122	22	1144	2%
TOTAL	853	26	879	357	4	361	1210	30	1240	2%

*Areas where all accidents were tabulated --midblock and intersection.

**Only one fatal accident recorded, Major street, Other category.

APPENDIX C

This Appendix contains the following tables relating to Accident Findings:

C-1, Major Street Miles by Width and Land Use (2-Way Streets)

C-2, Major Street Miles by Width and Land Use (1-Way Streets)

C-3, Collector Street Miles by Width and Land Use (2-Way Streets)

C-4, Collector Street Miles by Width and Land Use (1-Way Streets)

C-5, Local Street Miles by Width and Land Use (2-Way Streets)

Table C-1. Major Street Miles* by Width and Land Use (2-Way Streets)

Width Feet**	Land Use (Both Sides)								
	Retail-Retail	Office-Office	Motel-Motel	Residential-Residential	Apartment-Apartment	Retail-Offices, Motel or Industrial	Residential-Apartment	All Other Combinations	TOTAL
<=26	0.0	0.0	0.0	0.11	0.0	0.0	0.0	0.0	0.11
27-28	0.0	0.0	0.0	0.57	0.0	0.0	0.0	0.0	0.57
29-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.43	0.43
31-32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33-34	0.0	0.0	0.0	0.29	0.0	0.0	0.0	0.0	0.29
35-36	0.0	0.0	0.0	0.73	0.21	0.0	0.27	0.0	1.21
37-38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.44	0.41	0.0	0.68	0.22	0.51	0.32	1.96	4.54
41-42	0.27	0.0	0.0	2.76	0.0	0.0	0.0	0.25	3.27
43-44	0.19	0.0	0.0	2.64	0.0	0.13	0.13	1.82	4.89
45-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47-48	0.09	0.15	0.0	0.34	0.0	0.08	0.0	0.0	0.66
49-50	0.29	0.0	0.0	0.96	0.0	0.06	0.0	0.11	1.42
51-52	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.08
53-54	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.27	0.36
55-56	0.88	0.75	0.0	0.0	0.25	0.0	0.0	0.65	2.53
57-58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59-60	1.17	0.05	0.16	2.16	0.30	0.42	0.56	0.58	5.42
61-62	0.0	0.0	0.13	0.05	0.0	0.0	0.0	0.09	0.26
63-64	0.16	0.0	0.11	0.0	0.0	0.0	0.0	0.14	0.41
65-66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67-68	0.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.64
69-70	2.26	0.0	0.0	0.0	0.0	0.28	0.0	0.54	3.08
71-76	0.43	0.23	0.0	0.0	0.26	0.43	0.0	0.11	1.46
>=77	0.50	0.12	0.0	0.0	0.0	0.13	0.0	0.0	0.75
TOTAL	7.31	1.89	0.40	11.30	1.24	2.03	1.27	6.95	32.38

*1 mile = 1.6 kilometers. **1 foot = 0.3 m.

Table C-2. Major Street Miles* by Width and Land Use (1-Way Streets)

Width Feet**	Land Use (Both Sides)								
	Retail-Retail	Office-Office	Motel-Motel	Residential-Residential	Apartment-Apartment	Retail-Offices, Motel or Industrial	Residential-Apartment	All Other Combinations	TOTAL
<=26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-28	0.0	0.0	0.0	0.0	0.73	0.0	0.21	0.0	0.94
29-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33-34	0.0	0.0	0.0	0.0	0.11	0.0	0.0	0.0	0.11
35-36	0.23	0.23	0.0	0.0	0.0	0.08	0.0	0.0	0.53
37-38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.15	0.27	0.0	0.0	0.57	0.0	0.30	0.33	1.62
41-42	0.29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29
43-44	0.38	0.20	0.0	0.0	0.0	0.12	0.0	0.08	0.77
45-46	0.25	0.07	0.0	0.0	0.0	0.0	0.0	0.07	0.40
47-48	0.28	0.08	0.0	0.0	0.0	0.08	0.0	0.0	0.43
49-50	1.96	0.0	0.0	0.0	0.0	0.67	0.0	0.20	2.83
51-52	0.08	0.28	0.0	0.0	0.0	0.08	0.0	0.0	0.36
53-54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55-56	0.54	0.96	0.0	0.0	0.0	0.40	0.0	0.18	2.08
57-58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59-60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61-62	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
63-64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65-66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67-68	0.26	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.33
69-70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71-76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>=77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	4.41	2.08	0.0	0.0	1.42	1.41	0.52	0.86	10.70

*1 mile = 1.6 kilometers. **1 foot = 0.3 m.

Table C-3. Collector Street Miles* by Width and Land Use (2-Way Streets)

Width Feet**	Land Use (Both Sides)								
	Retail-Retail	Office-Office	Motel-Motel	Residential-Residential	Apartment-Apartment	Retail-Offices, Motel or Industrial	Residential-Apartment	All Other Combinations	TOTAL
<=20	0.0	0.0	0.0	0.16	0.0	0.0	0.0	0.0	0.16
21-22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-28	0.0	0.11	0.0	0.10	0.0	0.0	0.0	0.0	0.21
29-30	0.0	0.0	0.12	0.76	0.0	0.0	0.0	0.0	0.88
31-32	0.0	0.0	0.0	0.10	0.0	0.0	0.0	0.0	0.10
33-34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.34	0.34
35-36	0.0	0.0	0.0	1.74	0.0	0.0	0.0	0.0	1.74
37-38	0.0	0.0	0.0	0.20	0.0	0.0	0.0	0.0	0.20
39-40	0.0	0.0	0.0	6.50	0.53	0.10	0.27	1.43	8.84
41-42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.0	0.0	0.61	0.10	0.0	0.0	0.09	0.80
45-46	0.0	0.0	0.0	0.14	0.0	0.0	0.0	0.0	0.14
>=47	0.0	0.35	0.10	2.49	0.42	0.0	0.38	0.97	4.72
TOTAL	0.0	0.46	0.23	12.80	1.06	0.10	0.65	2.84	18.13

*1 mile = 1.6 kilometers. **1 foot = 0.3 m.

Table C-4. Collector Street Miles* by Width and Land Use (1-Way Streets)

Width Feet**	Land Use (Both Sides)								
	Retail-Retail	Office-Office	Motel-Motel	Residential-Residential	Apartment-Apartment	Retail-Offices, Motel or Industrial	Residential-Apartment	All Other Combinations	TOTAL
<=20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25-26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27-28	0.0	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.10
29-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31-32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33-34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35-36	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.09
37-38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39-40	0.0	0.0	0.0	0.0	0.20	0.11	0.0	0.38	0.70
41-42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43-44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45-46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>=47	0.0	0.18	0.0	0.0	0.10	0.0	0.0	0.0	0.28
TOTAL	0.0	0.28	0.09	0.0	0.31	0.11	0.0	0.38	1.17

*1 mile = 1.6 kilometers. **1 foot = 0.3 m.

Table C-5. Local Street Miles* by Width and Land Use (2-Way Streets)

Width Feet**	Land Use (Both Sides)								
	Retail-Retail	Office-Office	Motel-Motel	Residential-Residential	Apartment-Apartment	Retail-Offices, Motel or Industrial	Residential-Apartment	All Other Combinations	TOTAL
<=20	0.0	0.0	0.0	4.34	0.0	0.0	0.0	0.0	4.34
21-22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23-24	0.0	0.0	0.0	10.18	0.0	0.0	0.0	0.10	10.28
25-26	0.0	0.0	0.0	6.22	0.17	0.0	0.0	0.0	6.39
27-28	0.0	0.0	1.00	7.61	1.65	0.0	0.51	0.05	10.82
29-30	0.0	0.25	0.12	13.85	0.52	0.0	0.0	0.16	14.89
31-32	0.0	0.0	0.0	9.79	1.74	0.0	0.0	0.0	11.53
33-34	0.0	0.0	0.0	9.70	1.05	0.0	0.16	0.13	11.04
35-36	0.08	0.08	0.0	15.94	1.07	0.0	0.41	0.64	18.21
37-38	0.0	0.0	0.17	0.32	0.0	0.0	0.0	0.09	0.58
39-40	0.08	0.11	0.0	11.78	0.21	0.0	0.98	0.45	13.61
41-42	0.0	0.0	0.0	0.50	0.0	0.0	0.0	0.0	0.50
43-44	0.0	0.25	0.0	0.64	0.0	0.0	0.0	0.0	0.89
45-46	0.0	0.0	0.0	1.99	0.0	0.0	0.0	0.0	1.99
>=47	0.13	0.17	0.0	0.06	0.27	0.17	0.10	0.13	1.02
TOTAL	0.29	0.85	1.29	92.91	6.67	0.17	2.16	1.75	106.09

*1 mile = 1.6 kilometers. **1 foot = 0.3 m.

APPENDIX D - MATERIAL USED IN STATISTICAL ANALYSIS

Table D-1, Combinations for Major Streets

Table D-2, Combinations for Collector Streets

Table D-3, Combinations for Local Streets

Accident Rate Transformation

Figure D-1, Mean vs Standard Deviation for Accidents per Million Vehicle Miles

Figure D-2, Mean vs Standard Deviation for Accidents per Mile per Year

Figure D-3, Mean vs Standard Deviation for Transformed Accident Rate, Y

Figure D-4, Mean vs Standard Deviation for Transformed Accident Rate, Z

Description of Analysis Procedures (Bonferroni Procedure, Scheffe' Procedure)

Table D-4, Comparisons of Land Use for Major Streets

Table D-5, Comparisons by Parking Type for Major Streets

Table D-6, Comparisons for Collector Streets

Table D-7, Comparisons of Land Uses for Local Streets

Table D-8, Comparisons of Parking Type for Local Streets

Table D-1. Combinations for Major Streets

Land Use	Parking Utilization Level*	Number of Combinations															
		No Parking	Parallel One Side	Parallel Both Sides	Parallel & Skip Parallel	Skip Parallel	Parallel & 22½° Angle	22½° Angle	30° Angle One Side	Parallel & 30° Angle	30° Angle	High Angle One Side	Parallel & High Angle	Skip Parallel & High Angle	High Angle
Retail	1	17		2		2									1
	2		1	6											
	3		2	20		3					1				
	4			23		1		10		1	1				4
Retail/ Office	1	10	1	1											
	2			1						1	1				
	3			4							2				
	4			3		3		7			2				1
Office	1	4													
	2			2	1		2		1						
	3		2	1			1	3			1				
	4			7		1		5					1		2
Single Family Residential	1	10	2	16											
	2			12											1
Single Family/ Apartment	1	11		1											
	2		1												
	3		1	4											
	4			3											
Apartment	1	4													
	2		3												
	3		7	4											1
	4			4											1
Miscellaneous	1	3		1											
	2		1	1	1									1	
	3			1		1									
	4													1	1
Retail and Single Family Residential	1	3		1											
	2		1	2											
	3			2											
	4			2											
Retail and Apartment	1	3													
	2			1											
Retail and Misc.	1	4													
	2		2	1											
	3			3								1			
	4					1									
Office and Single Family Residential	1	3		1											
Office and Apartment	2			1											
	3			1											
Office and Misc.	1	1									1				
	3		1								1				
	4			2				1				1			
Single Fam. Resid. & Misc.	1	6	1	3											
	4			1											
Apartment and Misc.	1		1	2											

*1 = very low, 2 = low, 3 = moderate, 4 = high.

Table D-2. Combinations for Collector Streets

Land Use	Parking Utilization Level*	Number of Combinations							
		No Parking	Parallel One Side	Parallel Both Sides	Skip Parallel	22½° Angle	Parallel and High Angle	High Angle
Retail and Office	2			1				
Office	1					1		
	2			1				
	3		1	1				
	4			1				
Single Family Residential	1			9				
	2			12				
Single Family Res. & Apart.	2			1				
Apartment	3			2				
	4			3				5
Miscellaneous	1			1				
	3			1	1			
	4							1
Retail and Apartment	1	1						
	4			1				1
Office and Misc.	2			1				
	3						1	
	4			1				
Single Family Residential and Misc.	2			2				

*1 = very low, 2 = low, 3 = moderate, 4 = high.

Table D-3. Combinations for Local Streets

Land Use	Parking Utilization Level*	Number of Combinations: No Parking	Parallel One Side	Parallel Both Sides	Parallel and High Angle	High Angle
Retail	2			1		
	3			1		1
	4			1		
Retail and Office	2				1	
	4					1
Retail and Single Family Residential	3			1		
Office	1		1			
	2		2	1	1	
	3			1		
	4			1	1	1
Office and Misc.	4			1		
Single Family Residential	1		13	96		
	2		4	211		
	3		4	66		
	4		1	29		
Single Family Residential and Apartment	2			3		
	3			6		
	4			8	1	
Single Family Resid. & Misc.	2		1	2		
	3			2		
Apartment	2			3		
	3		3	9		
	4		1	38		2
Apartment and Miscellaneous	1	1				
	4					1
Miscellaneous	1		2			
	2			3		
	3			2		

*1 = very low, 2 = low, 3 = moderate, 4 = high.

Accident Rate Transformation

The analysis of variance (ANOVA) technique is based upon comparing variances which are computed in different ways. In an ANOVA, the data are grouped into cells and the variance of the data is computed "within each cell," then the variance of the data is computed "between the cells" by using the cell means. The variance based on the cell mean is then compared with the average of the variances "within each cell." If there is a significant difference between the cell means, then these two ways of calculating the variance will yield different values. Because of this comparison procedure, a key assumption is that the variability of the responses within each cell is essentially the same for all cells. This translates into the requirement that the variation of accidents per MVM between locations in a given street group is roughly the same for all different groups. If the variability of the responses in a cell is proportional to the mean response for that cell, and if two cells have different mean responses, then they have different variances. This was the case with the parking study data. It is the average of these different variances that forms the "background noise" against which the difference in the means must be measured. Thus proportionality between the cell means and the cell variation results in a drastic reduction of the sensitivity of the ANOVA procedure.

For the parking study data (and typically for most accident data) the variation in the accident rate was proportional to the average accident rate when similar locations were considered as a group. For those groupings with more than one location, the group mean is plotted against the group standard deviation, as in Figures D-1 and D-2. The proportionality is clearly seen in the wedge shape of the points in these graphs. (If the variation was roughly constant regardless of the mean, then such graphs would show a horizontal band).

The traditional solution for this problem is to make a nonlinear transformation of the original response variable. By using a nonlinear transformation, the skewness of the response variable can be minimized, thus stabilizing

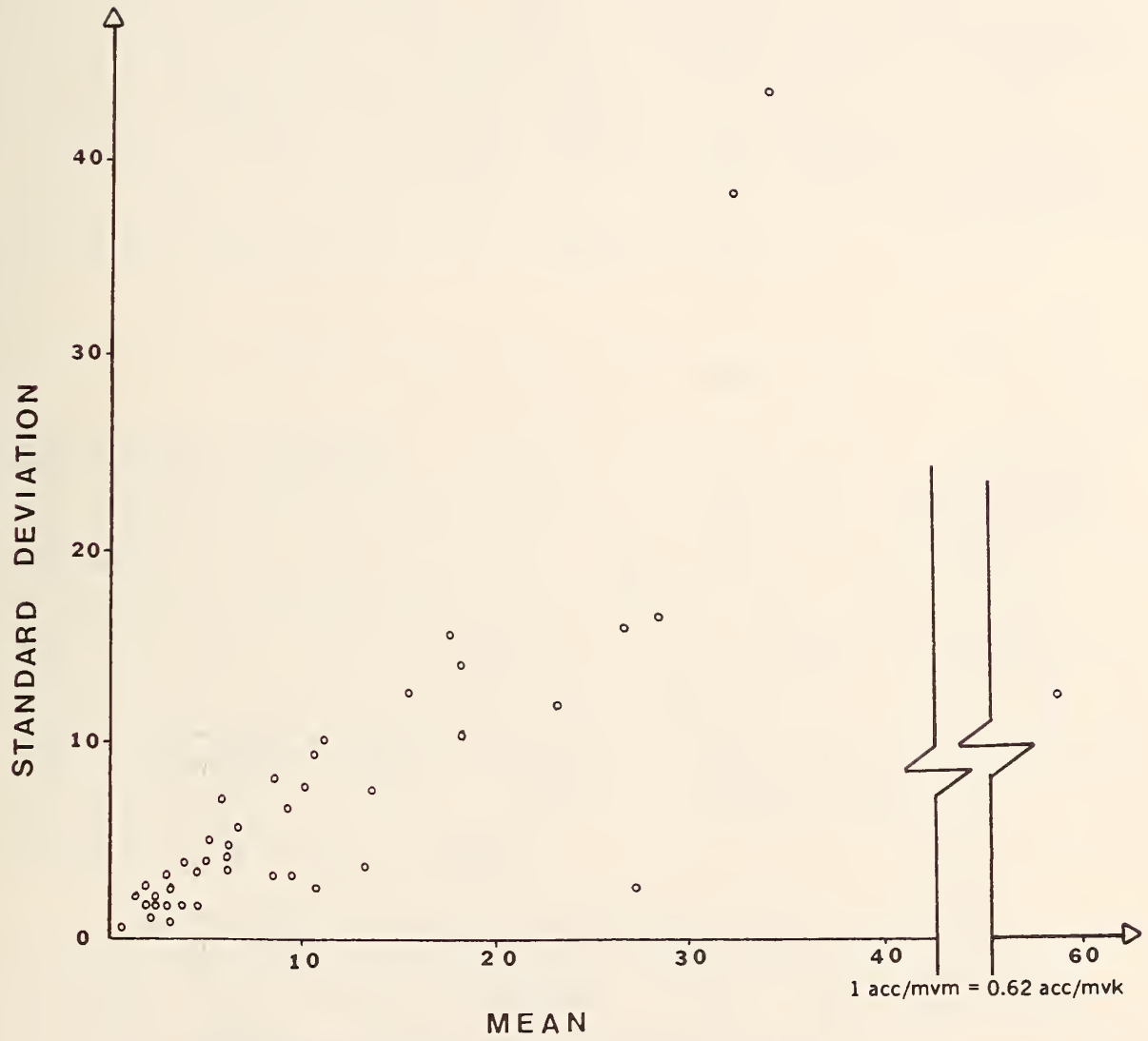


Figure D-1. Mean vs Standard Deviation for Accidents per Million Vehicle Miles

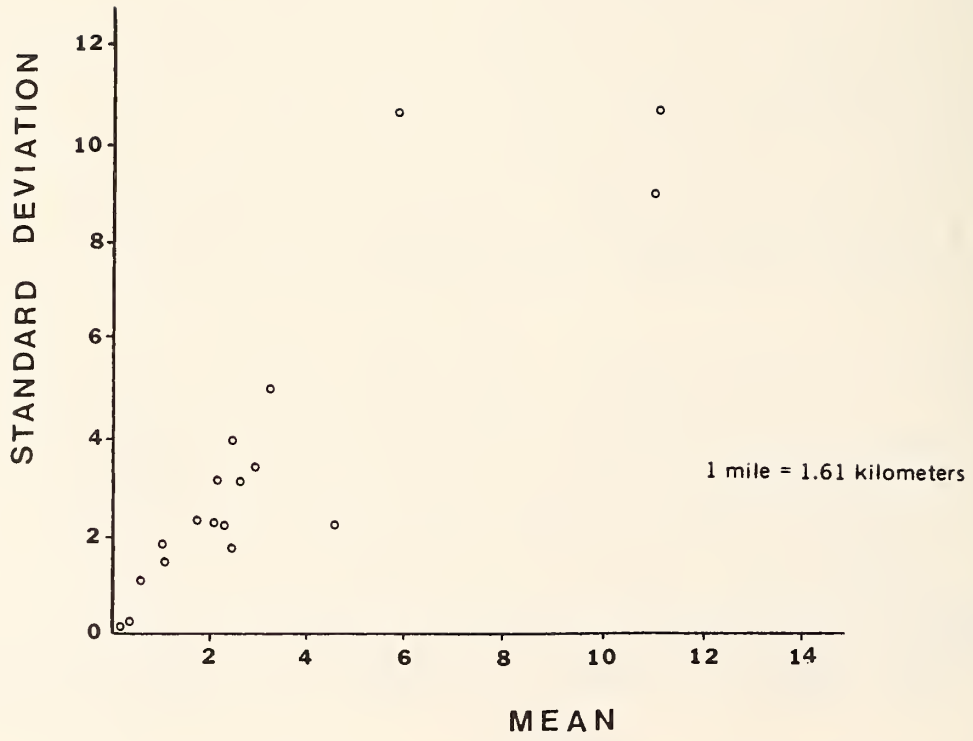


Figure D-2. Mean vs Standard Deviation for Accidents per Mile per Year

the variation within each cell, while maintaining the intrinsic relationship between the individual responses within each cell. For these data, the transformations used were $Y = \ln(Acc/MVM + 1)$ and $Z = \ln(Acc/MY + 1)$. Figures D-3 and D-4 show the standard deviation versus the mean for the Y and Z values for each of the groupings used in Figures D-1 and D-2. Here the desired horizontal bands are present.

By analyzing the groups with Y or Z as the response, the variability of the response is effectively homogenized for the various groups. This homogeneous variation within each group reduces the amount of background noise compared with an analysis using the untransformed accident rates. Since differences in groups have to be detected in the presence of this background noise, the reduced background noise leads to a more sensitive analysis. For this reason, the responses used in the analysis were the transformed accident rates Y and Z, as defined above.

Description of Analysis Procedures

Bonferroni Procedure: This is a modification of analysis of variance which allows specific comparisons, planned in advance, to be made. Because these comparisons may not be independent of each other, an adjustment is made in the effective significance level used for each comparison. Specifically a sum of squares with one degree of freedom is calculated for each comparison. When divided by the mean square error term from the overall analysis of variance, a statistic results which follows an F-distribution under the null hypothesis. This statistic is compared with the critical point from the appropriate F-distribution using a significance level of alpha.

As these tests are carried out on the individual comparisons, the probability of a type I error increases. Moreover, the dependence of the various comparisons makes it impossible to calculate a true overall alpha-level. However, an upper bound on the true overall alpha-level may be found by simply summing the alpha values of the individual tests.

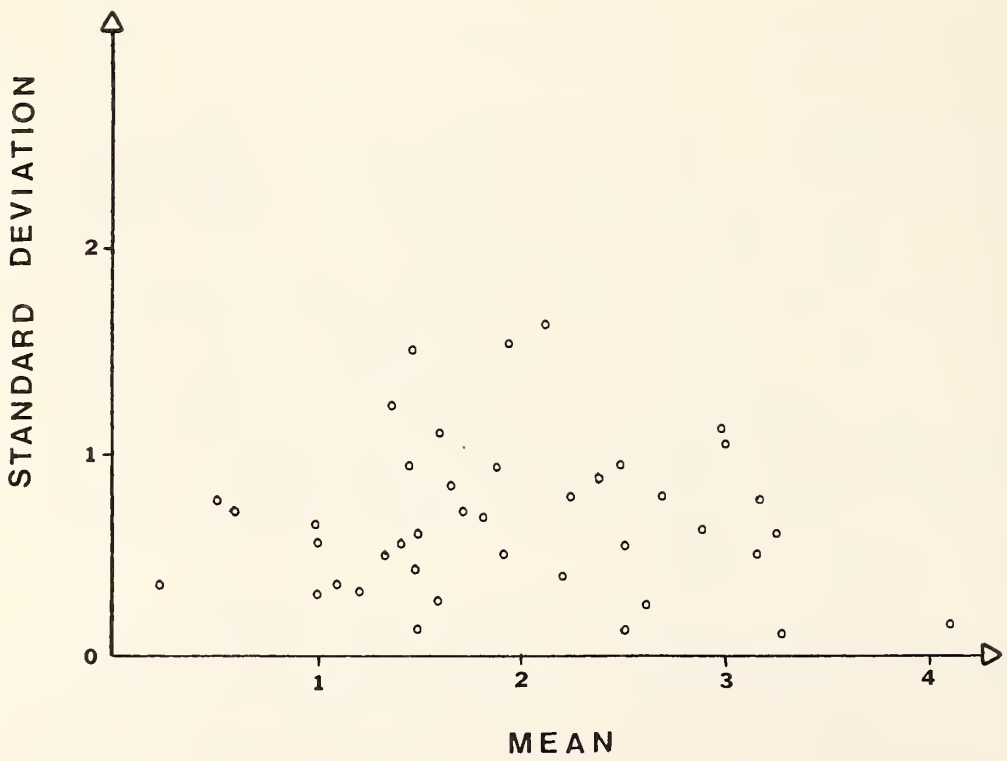


Figure D-3. Mean vs Standard Deviation for Transformed Accident Rate; Y

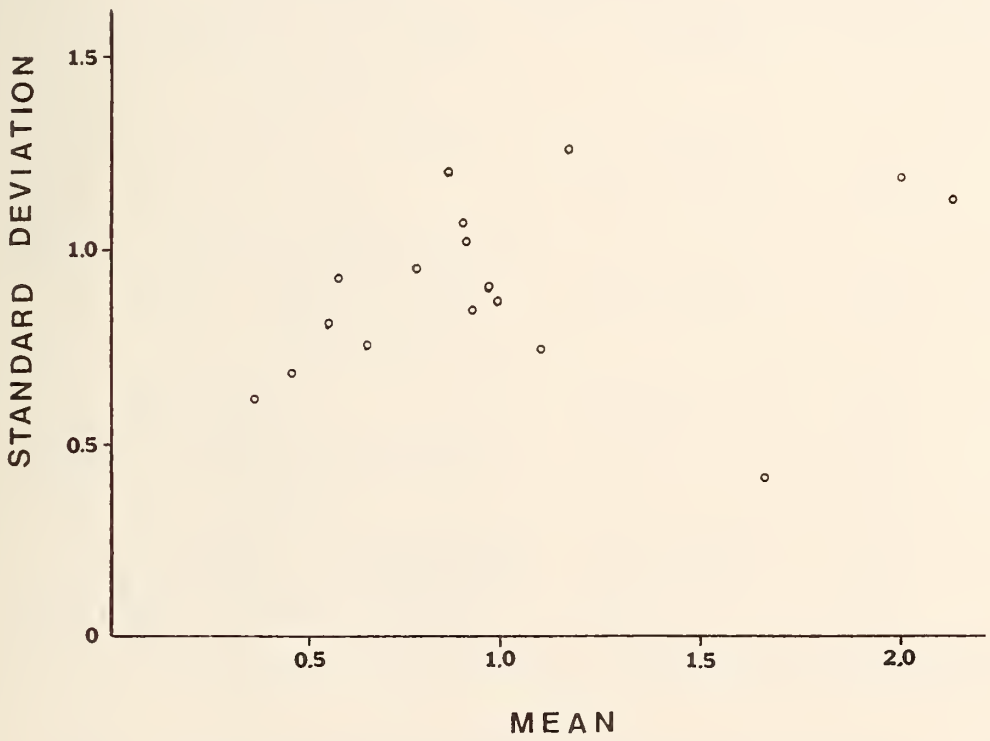


Figure D-4. Mean vs Standard Deviation for Transformed Accident Rate; Z

Scheffe' Procedure: This is a post hoc procedure which allows questions to be asked after the preliminary analysis of the data has been completed. In effect, any comparisons of cells or any comparison between different collections of cells may be made. For any one comparison a sum of squares is obtained as before, and this is compared with a critical value based on an F-distribution. The Scheffe' procedure differs from the Bonferroni procedure in the way the critical value is calculated. This value is inflated to give a true overall significance level (equal to the specified value) when all possible comparisons are simultaneously considered. If only a few comparisons are to be made, this procedure is very conservative. However, it does have the advantage of allowing the ranking of cell means and asking of specific questions based upon these ranked cell means.

The essential conservativeness of the Scheffe' procedure means that the results obtained are good, but its sensitivity suffers as a consequence. Thus, it is used in addition to the more sensitive Bonferroni procedure.

Reference: Applied Linear Statistical Models, Neter and Wasserman, Richard D. Irwin, publishers, Homewood, Illinois, p. 480 and p. 447.

Table D-4. Comparisons of Land Use for Major Streets

Comparison	Number of Locations	Significant	Nominal Alpha Level
Retail vs Retail & Office	80 vs 31	no	
Retail vs Retail & Single Family Residential	69 vs 11	no	
Retail vs Office	60 vs 21	yes	0.05
Retail vs Single Family Residential	25 vs 38	no	
Retail vs Apartment	62 vs 19	yes	0.005
Retail vs Misc. Uses	46 vs 7	no	
Retail & Office vs Office	25 vs 19	no	
Retail & Office vs Single Family Residential	12 vs 38	no	
Retail & Single Family Residential vs Single Family Residential	6 vs 38	no	
Office vs Single Family Residential	6 vs 22	no	
Office vs Apartment	14 vs 20	no	
Single Family Residential vs Single Family Residential & Apartment	26 vs 12	no	
Single Family Residential vs Apartment	10 vs 4	no	
Single Family Residential vs Misc. Uses	26 vs 4	no	
Single Family Residential & Apartment vs Apartment	20 vs 21	no	
Apartment vs Misc. Uses	10 vs 5	yes	0.05

Table D-5. Comparisons by Parking Type for Major Streets

Parking Types	Number of Locations	Significant	Nominal Alpha Level
None vs Parallel	63 vs 30	no	
None vs Parallel with Skips	17 vs 2	yes	0.025
None vs 30° Angle	1 vs 1	no	
Parallel vs Parallel with Skips	59 vs 12	no	
Parallel vs 22½° Angle	38 vs 28	yes	0.005
Parallel vs 30° Angle	55 vs 10	no	
Parallel vs High Angle	51 vs 11	no	
Parallel with Skips vs 22½° Angle	6 vs 24	no	
Parallel with Skips vs 30° Angle	8 vs 6	no	
Parallel with Skips vs High Angle	6 vs 8	no	
22½° Angle vs 30° Angle	22 vs 5	yes	0.005
22½° Angle vs High Angle	23 vs 9	no	
30° Angle vs High Angle	3 vs 5	no	
Parallel (both types) vs High Angle	4 vs 2	no	

Table D-6. Comparisons for Collector Streets

Comparison	Number of Locations	Significant	Nominal Alpha Level
PARKING TYPES			
Parallel vs High Angle	4 vs 6	no	
Parallel vs Parallel with Skips	1 vs 1	no	
LAND USES			
Office vs Single Family Residential	1 vs 12	yes	0.01
Office vs Apartment	2 vs 5	no	
Single Family Residential vs Single Family Residential & Apartment	12 vs 1	no	
UTILIZATION			
0.0 to 0.1 vs 0.1 to 0.5	9 vs 12	no	
0.1 to 0.5 vs 0.5 to 1.0	1 vs 1	no	
0.1 to 0.5 vs 1.0 up	4 vs 5	no	
0.5 to 1.0 vs 1.0 up	3 vs 4	no	

Table D-7. Comparisons of Land Use for Local Streets

Comparison	Number of Locations	Significant	Nominal Alpha Level
Retail vs Office	3 vs 3	no	
Retail vs Single Family	3 vs 306	yes	0.025
Retail vs Single Family & Apartment	3 vs 17	no	
Retail vs Apartment	3 vs 50	no	
Office vs Single Family	6 vs 323	no	
Office vs Single Family & Apartment	4 v 18	no	
Office vs Apartment	4 vs 52	no	
Single Family vs Single Family & Apartment	306 vs 17	yes	0.005
Single Family vs Apartment	311 vs 54	yes	0.005
Single Family & Apartment vs Apartment	17 vs 50	no	

Table D-8. Comparisons of Parking Type for Local Streets

Comparison	Number of Locations	Significant
Parallel One Side vs Parallel Both Sides	29 vs 452	no
Parallel vs Parallel & High Angle	10 vs 3	no
Parallel vs High Angle	40 vs 4	no

APPENDIX E

This Appendix supplements the Field Studies section, and contains information on:

Filming Procedure

Study Site Preparation

Film Reduction

Data Recording and Codes

Table E-1, Time-Lapse Data Codes

Figure E-1, Unparking Maneuvers

Table E-2, Speed and Lateral Placement, Parallel Parking

Table E-3, Speed and Lateral Placement, Angle Parking

Table E-4, Delay and Conflicts by Parking Layout

Filming Procedure

Time-lapse filming used a Super-8 Nizo 561 camera with a 7-56 mm zoom lens and automatic exposure control. A heavy-duty tripod with adjustable-length legs was utilized.

After potential camera locations were determined, building owners, managers, or tenants were contacted for filming permission. In two cases, a written "release" was required to protect the building owner, while in many cases permission was denied. One film had to be made from the top of a parked automobile. Analysis was difficult and time-consuming, due to the low camera angle. In two locations, filming was accomplished using bucket trucks furnished by the respective cities.

For those study locations with reasonably continuous traffic activity, the camera was run continuously. For locations with intermittent activity, the camera was turned on and off, capturing any activity of interest. Multiple films were made at several locations to obtain more data.

Study Site Preparation

At each study site, dimensions of streets, lanes and parking stalls were measured. Use of traffic lanes was recorded by direction.

A speed trap was laid out on each street at a location visible from the camera location to allow speed and delay analyses. The limits of this trap, usually 200 feet (60 m) in length, were marked with temporary pavement marking tape. The width and length of these markings varied with the camera viewing angle, camera distance, and street width.

Lateral placement marks were also provided using tape. These marks were installed parallel to traffic flow at 2 foot (0.6 m) increments, covering the roadway adjacent to parked vehicles.

Film Reduction

Films were analyzed using a Lafayette Super 8 projector with mechanical frame counter and hand-held control box. The projector could be operated from a distance of several feet and performed the following functions: continuous speeds ranging from 20 frames per second down to one frame per second, or one frame at a time per individual's control; all either forward or reverse.

There were a few difficulties encountered with the projector itself. The projected image was very small, making detail and distances difficult to estimate at times. This might have been corrected by the use of different lens. The mechanical frame counter occasionally stopped between digits, leading to a judgment whether to use the higher or lower frame number. A light emitting diode (LED) readout would have eliminated this problem. Occasionally the film slipped in the projector, particularly when multiple incidents necessitated alternating directions for accurate data reading. This caused a discrepancy in the actual frame numbers. Correction was made by reversing the film to a previously recorded incident and matching the proper film frame to the frame number, repositioning the film by hand. The problem of film slippage was the most difficult and time-consuming to control.

Of the five persons involved in the film analysis, a minimum of two worked together on each film. For uniformity, some films and data were reread and spotchecked by two other persons.

Data Recording and Codes

A systematic procedure was established in the analysis of the films. In preparation, the projector was loaded with a film and the frame counter was set so that the first pictoral frame was #001. Data were recorded on computer code sheets, using numerical coding.

A detailed description of the codes used in recording data is given below and in Table E-1.

Columns 1-3: Vehicle Number --Assigned to each new vehicle as it begins movement within the study area.

Column 4: Vehicle Type --As listed in Table E-1. The category "Other" included such types as motorcycles, bicycles, buses, land rovers, and other vehicles that did not fall into the specific categories listed. Further explanation was included in the final "Comments" columns.

Column 5: Vehicle Movement --Indicating action taken by each vehicle within the study area; through, parking, unparking or stopping to stand.

Column 6: Lane Number --Indicating the initial location of the vehicle in the study area. Lanes were numbered from right to left from the viewer's position.

Column 8: Lane Change --Indicated whether through vehicle made lane change.

Columns 9-10: Recorded original lane number and final lane number. This included changes made from original lane, back to original lane. If half of the vehicle crossed the lane line within the trap length, then a change was recorded.

Columns 11-12: Lateral Placement --Denoted the lateral location of each vehicle in the lane adjacent to each parking lane, to the nearest 0.5 foot (0.15 m). Lateral placement markings were 2 feet (0.6 m) apart, center-to-center.

Columns 15-19 and 21-25: Speed Frames --Frame numbers were recorded to the nearest one-half frame for each vehicle as it passed the be-

Table E-1. Time-Lapse Data Codes

Column		
1- 3	Vehicle No.	1-999
4	Vehicle Type	Car -1 Pickup -2 Pickup w/camper -3 Van -4 Truck -5 Other -6
5	Vehicle Movement	Through -1 Parking -2 Standing -3
6	Lane Number	Right Lane -1 Next -2 Next -3 Next -4
8	Lane Change	No -1 Yes -2
9-10	Initial Lane No. - Final Lane No.	
11-12	Lateral Placement (Distance from reference line)	
15-19, 21-25	Speed Frame numbers for position of vehicle at each mark on street (to nearest ½ frame)	
28	Delay Factors	No Delay -0 Parking Veh. -1 Unparking Veh. -2 Unparking/Parking Veh. -3 Pedestrian -4 Standing Veh. -5 Downstream Traffic -6 Unknown -7 Other -9

Table E-1. Time-Lapse Data Codes (Continued)...

Column	
29	Conflicts (through vehicle delay) None -0 Other-Through Vehicle -1 Parking Veh. -2 Unparking Veh. -3 Pedestrian -4 Door Opening -5 Standing Veh. -6 Other -7
32-35 37-40 42-45	Parking Time Frame #1 -Begins Parking Frame #2 -Clears Lane Frame #3 -Completes Maneuver
48-51 53-56 58-61	Unparking Time Frame #1 -Begins to Move Frame #2 -Encroaches Lane Frame #3 -Clears Parking Lane
64	Upstream Parking Vehicle Type No Vehicle -0 Others same as for Column 4
65	Door Opening on Traffic Side No -1 Yes -2
66	Downstream Parking Vehicle Type No Vehicle -0 Others same as for Column 4
67	Backing in on Parallel Parking No -1 Yes -2
68	Type of Unparking (Angle Slots) Type 1, 2 or 3
69-80	Vehicle Identification and Remarks

ginning and ending marks for the speed trap. Reference points on the cars were either the front wheels or rear wheels, whichever were closest to the viewer, to be consistent within each film.

Column 28: Obvious Delay Causing Factors --Delays were documented for through vehicles that slowed perceptibly in the study area for any reason. Factors included in the "Other" category included delays caused by a downstream traffic signal out of the study area.

Column 29: Conflicts --Observed when through vehicles had to swerve or stop quickly to avoid a possible accident.

Columns 32-35, 37-40, 42-45: Parking Time Frames

First Frame Number --To indicate the first movement in the parking process.

--For Angle Parking and Head-in Parallel Parking the movement began when the vehicle began to turn in the lane toward the parking slot.

--For Back-in Parallel Parking the movement began when the vehicle stopped in the lane to back into the slot.

Second Frame Number --The point at which the vehicle finally cleared the lane of traffic.

Third Frame Number --When vehicle completed the parking maneuver and stopped completely in the slot.

Columns 48-51, 53-56, 58-61: Unparking Time Frames

First Frame Number --When the vehicle

first began any unparking movement.

Second Frame Number --Point at which the vehicle encroached on the travel lane.

Third Frame Number --Vehicle cleared the parking slot or parking lane completely. (Some parallel-parked vehicles traveled down the empty parking lane before entering the travel lane).

Column 64: Type of vehicle parked upstream of the parking/unparking vehicle being recorded.

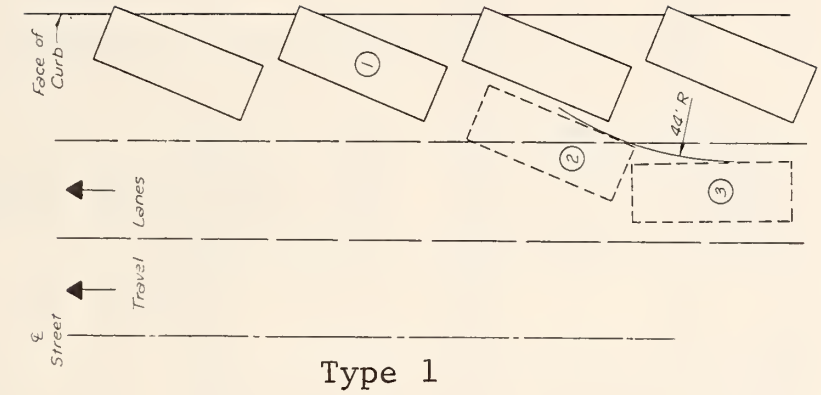
Column 65: Whether or not doors were opened into the traffic lane for parked and standing vehicles.

Column 66: Type of vehicle parked downstream of the parking/unparking vehicle being recorded.

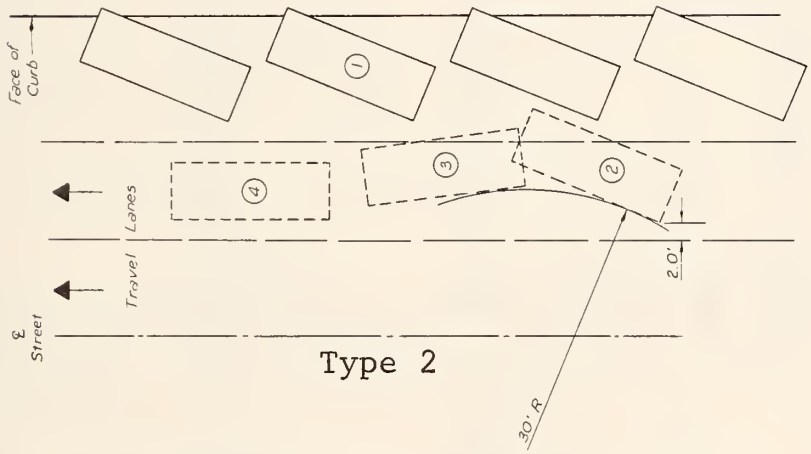
Column 67: Indicated whether or not a vehicle backed into a parallel parking slot, as opposed to pulling in head first.

Column 68: Type of maneuver used in unparking from an angled slot. Coding for these maneuvers was as shown in Figure E-1.

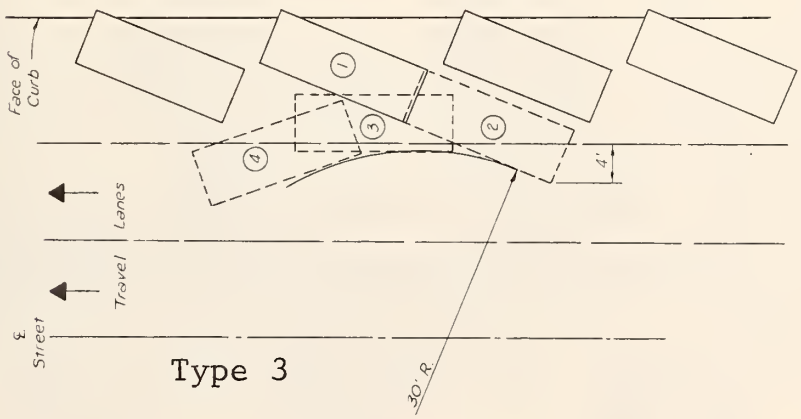
Columns 69-80: Used for vehicle descriptions and comments.



Type 1



Type 2



Type 3

Figure E-1. Unparking Maneuvers
Source: Reference 5

Table E-2. Speed and Lateral Placement
Parallel Parking

Type Parking	Location	Adjacent Lane Width (feet)*	Placement (ft)* Lateral No.	Lateral Place	Through Vehicles No.	Through Vehicles (MPH)**	Rate of Flow (VPH) where Applicable
Parallel (unmarked)	Clinch Ave.	23.0(c-c)***	92	12.2	61	15.2	400
	Elf St.	30.0(c-c)	8	11.5	9	15.4	
	Chestnut St.	38.5(c-c)	36	12.9	32	21.1	150
	Leavenworth St.	19.3	61	12.8	59	18.4	120
	Fulton St.	44.0(c-c)	47	12.8	70	18.9	
	SUBTOTAL (Avg.)		244	12.5	231	17.7	
Parallel (varying stall lengths)	9th St.	21.8	413	13.0	407	23.7	
	Clement St.	27.0	181	16.2	170	22.4	780
	S.Temple St.	20.0	179	13.2	295	30.9	1250
	18th St.	47.0(c-c)	19	15.0	44	17.3	
	Social Hall Ave.	52.2(c-c)	26	16.2	53	15.8	200
	Clement St.	21.7	98	14.0	93	16.0	840
	SUBTOTAL (Avg.)		916	13.9	1062	24.3	
Parallel (w/8' neutral zone)	High St.	19.0	36	11.2	165	24.5	440
	High St.	18.2	35	13.0			
	Lamar St.	25.0	144	16.3	229	20.0	640
	Lamar St.	19.2	71	12.8			
	SUBTOTAL (Avg.)		286	14.4	394	21.8	
Parallel (w/18' neutral zone)	10th St.	20.2	99	12.8	211	22.1	
	10th St.	19.1	81	11.6			
	Scott St.	19.5	89	11.3	307	23.1	990
	Scott St.	20.5	130	13.2			
	SUBTOTAL (Avg.)		399	12.4	518	22.8	
	PARALLEL TOTAL (Avg.)		1845		2205	22.8	

*1 ft. = 0.3 m. **1 MPH = 1.6 KPH. ***Curb face to curb face.

Table E-3. Speed and Lateral Placement
Angle Parking

Type Parking	Location	Adjacent Lane Width (feet)*	Placement (ft)* No.	Placement (ft)* Lateral Place	Through Vehicles No.	Through Vehicles (MPH)**	Rate of Flow (VPH) where Applicable	Comments
22½°	Indiana St.	24.1	68	17.8	88	20.4	410	
Angle	Cypress St.	23.2	53	16.7	98	16.0	380	Left & right side
	Cypress St.	23.0	43	16.2				
	N. 2nd St.	23.0	8	16.1	57	19.2	270	Left & right side
	N. 2nd St.	23.0	18	16.2				
	Pine St.	24.3	172	16.9	344	18.3	870	
	SUBTOTAL (Avg.)		362	16.9	587	18.4		
40°-	Main Ave.	30.4			166	24.4	690	40°
45°	Main Ave.	30.4	70	21.1	144	24.2		40°
Angle	High St.	29.6	383	21.4	239	15.6	600	45°
	Clement St.	31.8	67	16.4	93	16.0	830	45°
	9th St.	26.2	13	21.6	57	20.4		45°
	18th St.	47.0(c-c)***	31	20.6	44	17.3		45° w/parallel
	SUBTOTAL (Avg.)		564	20.7	743	19.6		
60°	Fulton St.	44.0(c-c)	25	21.4	70	18.9		w/parallel
Angle	Fulton St.	30.3	47	22.3	84	21.8		
	SUBTOTAL (Avg.)		72	22.0	154	20.4		
90°	8th St.	55.7(c-c)	20	23.3	16	19.4		w/90° angle
Angle	Chestnut St.	28.5	9	23.3	31	18.9	130	
	Leavenworth	27.8	49	19.4	82	19.3	210	
	SUBTOTAL (Avg.)		78	20.8	129	19.2		
	ANGLE TOTAL (Avg.)		1076		1613	19.1		

*1 ft. = 0.3 m. **1 MPH = 1.6 KPH. ***Curb face to curb face.

Table E-4. Delay and Conflicts by Parking Layout

Type Parking	Delays				Number of Conflicts by Type						
	Number Undelayed	Number Delayed	Proportion Delayed	Avg.Sec. Delay	1	2	3	4	5	6	7
Parallel (unmarked)	161	22	12%	7.0		2	1			1	
Parallel (varying stalls)	905	33	4%	5.4		2			1	1	
Parallel (w/8' neutral zone)	394	77	16%	6.2		8	2		1		1
Parallel (w/18' neutral zone)	518	111	18%	5.5	3	7	1	3	1	1	
22½° Angle	587	109	16%	7.2		1	5		1	6	
40° - 45° Angle	549	20	18%	9.0	5	3	7	2	1	5	1
60° Angle	84	5	6%	5.4		1				2	
90° Angle	129	11	8%	6.5		1		1			

*U.S. GOVERNMENT PRINTING OFFICE : 1979 0-630-142/256

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FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

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* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD-2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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